

The AMSAT[®] Journal



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Bill Hook, W3QBC



Emily Clark, N1DID, provides a hands-on demonstration of satellite communications at the Cal Poly CubeSat Conference. K7RR (SK) at left looks on. See page 4.



Richard Crow, N2SPI, shows you how to build the uplink side of this antenna in this issue. See page 26.

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AMSAT Announcements

- The AMSAT QSL enclosure form is printed on page 8 in this issue after several months of absence. Please use it to encourage those that you send QSL cards to join and support our organization. It only takes a minute and could add a member or two to the group. Thanks!
- If you are a federal employee please see the ad on page 25. AMSAT can benefit from your CFC contributions!
- The AMSAT Board of Directors has announced new Senior Officers for the organization. Please check the masthead on the next page (page 3) for a listing of the new officers and a listing of the Board of Directors.
- Thank you for your support of AMSAT!

AMSAT's Mission

AMSAT is a non-profit volunteer organization which designs, builds and operates experimental satellites and promotes space education. We work in partnership with government, industry, educational institutions and fellow Amateur Radio societies. We encourage technical and scientific innovation, and promote the training and development of skilled satellite and ground system designers and operators.

AMSAT's Vision

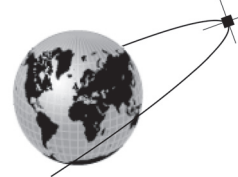
Our Vision is to deploy high earth orbit satellite systems that offer daily coverage by 2009 and continuous coverage by 2012. AMSAT will continue active participation in human space missions and support a stream of LEO satellites developed in cooperation with the educational community and other amateur satellite groups.





APOGEE VIEW

by Rick Hambly, W2GPS • w2gps@amsat.org



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Eagle Activities

It is a very busy time of the year. In the past few weeks I attended a series of important meetings. The first was a meeting at the Pentagon to brief the U.S. Air Force Space Command on AMSAT and the Eagle satellite. Next I traveled to Maryland's Eastern Shore and NASA's Wallops Island to discuss the University of Maryland's proposal to host an AMSAT satellite laboratory. Finally I met with a prestigious Washington DC law firm to discuss AMSAT's responsibilities regarding U.S. export regulations, including ITAR [1]. VP Engineering Bob McGwier N4HY accompanied me to all of these meetings. In addition, Director Tom Clark, K3IO, and Eagle project member Bob Davis, KF4KSS, attended the lab meeting.

I did find time to go out and have some ham radio fun. On the weekend of September 9th I volunteered as an operator at Marty's, W3SO, contest site in Altoona, PA for the ARRL VHF QSO Party. I spent most of the time operating the 432 MHz station with 1 kW into a 40-element beam at 120 feet on the Eastern Continental Divide. During slow periods I had QSOs with stations in Maine and North Carolina. OK, it has nothing to do with AMSAT, but it was a much needed break from the pressure of deadlines, work and AMSAT responsibilities.

Looking back on my last Apogee View I realize that my report on the Eagle meeting in San Diego may have left some of you wondering about the Eagle band plan after the decision of the team to use the S1 band (2400 MHz) for the new C-C Rider uplink. This change also suggests that we need a new name for this critically important payload so let be call it the Advanced Communications Payload (ACP) for now. I want to assure everyone that the larger Eagle project team and AMSAT leadership are reviewing the implications of these decisions. I hope a final announcement on the outcome of this review will be made at the 2006 Symposium. Rest assured that we are considering technical issues, feedback from our members and international concerns.

HPSDR and TAPR

Last month I discussed AMSAT and TAPR support for the High Performance Software Defined Radio (HPSDR) project. See <http://hpsdr.org/> for more information. The first real public exposure for the HPSDR group was at the recent 25th annual TAPR and ARRL

Digital Communications Conference. Those who attended the DCC got a preview of more to come at the AMSAT Symposium.

AMSAT's Software Defined Transponders (SDXs) and Advanced Communications Payload (ACP, previously C-C Rider) will borrow heavily on the work being done by the HPSDR group. It is no surprise that many of the same people are volunteering on both HPSDR and Eagle teams. You will hear more about this as the Eagle project progresses.

2006 Space Symposium

I am always surprised that only about 5% of AMSAT's membership attends the annual Space Symposium. If you attended this year you should have learned more about AMSAT's projects and inner workings. I hope you were pleased. Did you meet new people or have a special experience at the Symposium? Share your experience by sending an e-mail to the Journal editor Ed Long, WA4SWJ, at journal@amsat.org. By the time you read this we should know where the 2007 Symposium will be held. How about mentioning it at your local club meetings and hamfests?

AMSAT Needs You!

AMSAT needs your support to achieve our goals. Our Eagle Build Campaign for 2006 is nearing our goal of \$150,000. Please call the office or visit the AMSAT Web Store to make your donation. All donations of \$120 or more qualify for President's Club status. For information on setting up a AMSAT hamfest booth or giving presentations at local ham clubs contact Martha at the AMSAT office (301) 589-6062 or your AMSAT Field Operations director, Gould Smith, WA4SXM, at wa4sxm@amsat.org.

73,
Richard M. Hambly, W2GPS
AMSAT President

[1] International Traffic in Arms Regulations (ITAR). These complex regulations include satellites and related intellectual information and services.



Third Annual CubeSat Developer's Workshop, 2006

by Dr. Stefan Wagener, VE4NSA, stefan_wagener@hotmail.com

and Emily Clarke, N1DID, n1did@amsat.org

Introduction

This year's CubeSat workshop (27-29, April) was held in San Luis Obispo, California, at California Polytechnic State University (Cal Poly) at the Advanced Technology Laboratories (ATL) facility and was hosted by the Aerospace Engineering Department under the direction of Professor Jordi Puig-Suari.

The concept of a 10 x 10 x 10cm (4 inch cube) as a fully functional satellite weighing no more than 1kg has grown tremendously and taken on a life of its own. Over one hundred eager participants attended from around the world including, Japan, Switzerland, Taiwan, Rumania, Turkey, Canada and the USA. They used the 2½ days to exchange information, learn from each other and engage in design, testing and operational presentations and open discussions. Many of these participants represented universities with new or existing CubeSat projects. Industrial partners and sponsors, among them Lockheed Martin, Boeing, Raytheon, Northrop Grumman, Vacco and the California Space Authority presented some of their ideas and new technologies as well as engaged students looking for future employment opportunities.

The program was very well organized by the students and staff of CalPoly, who did an excellent job keeping things running smoothly and on track. There was ample time for networking and many offline discussions centered on Amateur Radio use, ground stations and their operations. Almost all of the CubeSat teams are planning on using Amateur Radio frequencies, requiring licensed operators and strong guidance from the Amateur Radio satellite community. This presented a great opportunity for our AMSAT members to engage the participants. Emily Clarke, N1DID, presented her paper entitled "*AMSAT and Amateur Radio – Benefits for the CubeSat Community*" that discussed the commonalities and issues that both groups share. Emily's hands-on demonstrations were of great interest and resulted in a number of contacts on AO-51, AO-7 and VO-52. Appropriately, for this CubeSat workshop, Emily even demonstrated the reception of Cute 1.7 telemetry with a handheld and a simple whip antenna.

Dr. Paul Shuch, N6TX, AMSAT's new

Director of Education, also gave a presentation about his role, which included collecting a survey from the participants about their educational responsibilities.

Also in attendance from AMSAT were Cliff Buttschardt, K7RR (SK), the resident advisor to the CubeSat program at Cal Poly, Nick Pugh, K5QXJ, who is an advisor and mentor to the CAPE CubeSat team at the University of Louisiana at Lafayette and Dr. Stefan Wagener, VE4NSA, who is an advisor to the WinCube project in Winnipeg, Manitoba. All AMSAT members were actively involved in answering questions and promoting our interests.

A special thanks goes to our AMSAT members for taking the time to travel to San Luis Obispo and for making their expertise and knowledge available.

CubeSat Project Overview

The importance of the CubeSat concept for the educational community is obvious when one realizes that now over 60 universities and groups are registered with CalPoly in developing CubeSats, with thirteen CubeSats currently in orbit and another 23 awaiting launch (that we know about). The strong interest in these small satellites has also attracted commercial and government involvement in all areas of mission planning, parts procurement, funding, launch opportunities and payload development.

One commercial firm, Pumpkin, Inc. (<http://www.CubeSatkit.com/>) specializes in the development of ready-to-use CubeSat kits. Other vendors like the StenSat group are now developing UHF/VHF TNC radios specifically for these small satellites. VACCO Industries introduced a cold gas micro-propulsion system designed to fit into the CubeSat frame. Fueled by Isobutene, the five micro-thrusters can deliver a total of 34 N-sec of thrust over 62,000 minimum impulse bit firings. Because of the weight of such a system (made from titanium), a double CubeSat (10 x 10 x 20cm) is probably required, however we were all amazed at how much micro-miniaturization has advanced the process of attitude, control and determination. Interestingly, in the VACCO design, the valves and control electronics are built into the actual tank compartment and directly exposed to the propellant for maximum space efficiency.

CubeSat Team Presentations

The following is a synopsis of the presentations from teams that are currently working on CubeSat projects or are awaiting launch.

Cal Poly San Luis Obispo

Armen Toorian, a graduate student at CalPoly, opened the conference and spoke about important lessons learned, both as a member of the Cal Poly CP-1 and CP-2 projects but also as a member of the core team at Cal Poly. One lesson learned was to start working on a functional ground station early in the project. According to his team's experience, groups were late in their ground station set-up, testing and operation, which resulted in ineffective or failed communications. This delay contributed to one team being unprepared to recover their CubeSat when it failed. This important aspect demonstrates where AMSAT members can have a significant contribution if the universities provide us with information for early involvement.

Another important lesson is the need for having a beacon on the satellite so that it can be tracked and differentiated from other CubeSats deployed at the same time. Right after launch, a functional beacon is essential for identifying the satellite and when combined with telemetry, will provide for early satellite status information.

Additional discussion centered on the upcoming issue of all satellites having some form of de-orbiting ability to reduce the amount of space junk. For more information on this important topic go to <http://www.orbitaldebris.jsc.nasa.gov/>.

Montana State University

Danny Jacobs (Montana State University) provided an update on the "Electra" project, previously known as BarnacleSat because of the way it is attached to the launch vehicle. This CubeSat class spacecraft is modified to take advantage of the newly developed RocketPod form factor by Ecliptic Enterprises (see also report on the Ecliptic Enterprise presentation). Electra will contain an electrodynamic space tether connected to part of the launch vehicle. The concept is that by dragging against the earth's gravity field the tether will cause orbital perturbations that will accelerate orbital degradation and de-orbit the connected rocket fairing. The

satellite has a GPS on board to provide a precise location, and will transmit its location (including altitude) via APRS. This will be used in determining the success of the de-orbiting experiment.

Danny also discussed his concern about the proposed demonstration launch, which would be aboard a Falcon 1 (Space X, Spring 2007) launch from the Kwajalein launch site on the Marshall Islands. The equatorial launch location and the Malaysian primary payload requirements would result in an insertion orbit of a +/- 10-degree inclination. This would make it impossible for the ground station in Montana to hear the satellite. Danny's hope is to build a network of APRS equipped ground stations near the equator to provide precise location and plot drag if Electra is launched into that orbit.

National Cheng Kung University, Taiwan

The next presentation was by J.C. Jung from Taiwan (National Cheng Kung University). Their CubeSat called "PaceSat" for Platform for Attitude Control Experiment will use a three-axis stabilization system based on micro-momentum wheels gyroscopes and miniaturized magnetic coils for a projected five degree pointing accuracy. The satellite will also contain a micro sun sensor. Their double cube design is currently in the integration phase with a launch proposed in the next two years.

Texas A&M University

Allison Barnard and Alicia Broederdorf discussed their team's CubeSat project, SmartSat, which is under construction and testing at Texas A&M University. The primary scientific mission of SmartSat is to test shape memory alloys (SMAs) for deployment of solar panels. The satellite is designed around a DragonBall VZ processor and Yaesu VX-2R transceiver.

In addition, the satellite will use a magnetometer for attitude determination and gravity gradient boom coupled with three magnetorquers for stabilization and to keep the satellite nadir pointing. Experiments include an SXGA 1.3 megapixel CCD camera with built in JPEG compression. Power is provided by solar panels using 22% TecStar cells, 3.7V lithium ion batteries boosted by super capacitors.

Prior to the actual launch in 2008, the group plans to test components of the satellite during a high altitude balloon mission. The group plans to use radio amateur frequencies

in the 70cm band to track the payload using APRS during the balloon mission and during the payload recovery phase. Local radio amateurs located in the area of the launch will be requested to assist in tracking and reporting the payload location during the mission. For more information refer to their Web site (<http://sei.tamu.edu/CubeSat/CubeSat.htm>).

Auburn University

Eric Grimes (Auburn University) introduced AubieSat-1, which will test a new design for an ultraviolet sensor currently being developed by physicists at Auburn. Similar to SmartSat, the Auburn satellite will use a nitinol gravity gradient boom for stabilization in addition to dampening boxes containing a heavy viscous liquid. Rather than using microprocessors or microcontrollers, the satellite will use Altera Cyclone II FPGAs as the internal housekeeping unit. Power will be provided by SpectroLab 26.8% efficient improved triple-junction (IJT) solar cells.

Ecole Polytechnique Federal de Lausanne

The SwissCube project by the Ecole Polytechnique Federal de Lausanne was presented by Muriel Noca. This project is early in the planning stage and will involve 13 different laboratories in 5 different universities. Muriel presented the team structure, the work breakdown structure, budget and project objectives, which will be to study the NightGlow phenomena in the UV range from space. It will also contain a single photo avalanche diode experiment.

SwissCube will also be the first Swiss satellite in space and has wide ranging support from Swiss industry and the Swiss government.

The project team has already raised \$140K USD of the projected \$200K USD budget from industry alone.

Stanford University

Professor Bob Twiggs, formerly at Weber State University and now at Stanford University, started the second day of presentations with an overview of and a second presentation about the KatySat project. KatySat ("Kids Aren't Too Young for Satellites") is a CubeSat project that hopes to involve kids in the K-12 school environment. The project involves linking classrooms around the globe together through the Internet and a fully functional satellite in orbit. The students will engage in ground based "Star Wars" like adventures, "pinging" the satellite with mobile antennas and handheld radios and receiving codes to unlock information stored on computer servers. The students will also be able to upload data to the satellite that will be accessed by other students whenever the satellite passes over their location.

The overall objective of KatySat is to get younger students involved and interested

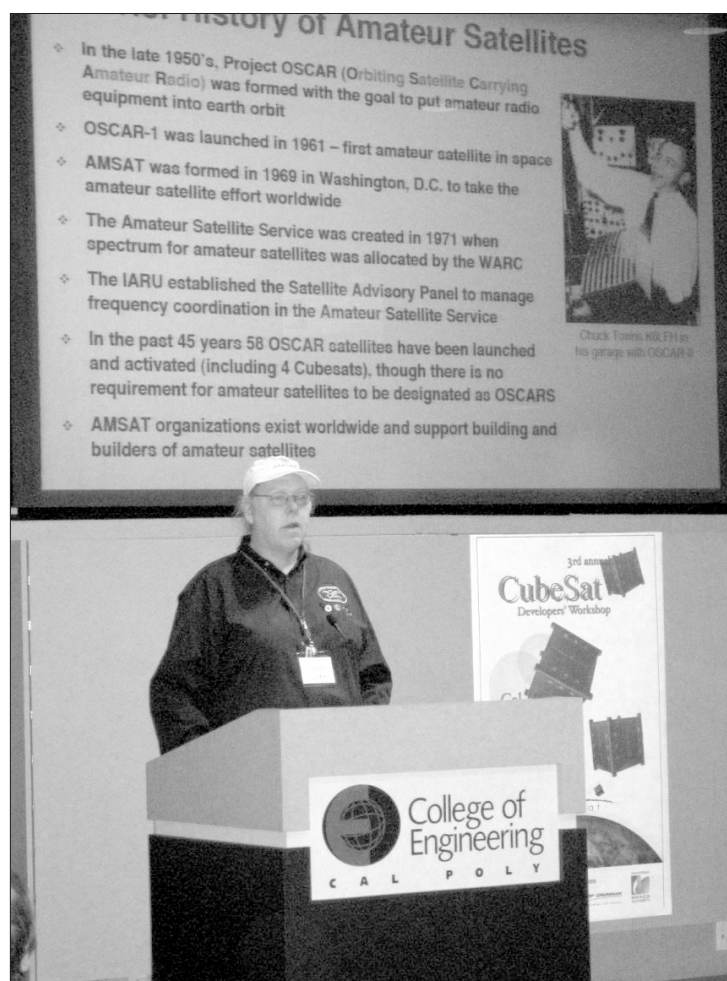


Figure 1: AMSAT presentation by Emily Clarke, N1DID.





Figure 2: Portable satellite operation demonstrated by Emily Clarke, N1DID, with Cliff Buttschardt, K7RR (SK), behind Emily with other CubeSat workshop participants observing.

in science and math through practical application of space related subjects. For more information see the KatySat Web site (www.katysat.org).

University of Illinois

Mike Dabrowski, a graduate from the University of Illinois now living in San Diego, presented the ION (Illinois Observing NanoSat) project. The satellite, a triple CubeSat, took three and half years to develop at a cost of \$170,000 and is awaiting launch in June of this year. Mike clearly favors an approach where you built the satellite first and then look for a launch opportunity, a process not shared or practiced by all CubeSat projects. In his opinion this prevents the project team from taking shortcuts since there isn't the pressure of chasing a launch date. Other groups voiced a different opinion saying that the goal of meeting launch dates keeps the teams engaged and progress is made.

One of the most frustrating experiences mentioned by most groups was enduring delay after delay of their launch date caused by problems with the primary payload. With many students having graduated and moved away prior to the launch, knowledge transfer and retention became an obvious challenge.

The ION satellite is using a Tekk KS 960 radio and a PicoPacket TNC. The group developed a new data transfer protocol on top of the AX.25 protocol for improved reliability. More information on the ION project can be found on their Web site (<http://CubeSat.ece.uiuc.edu>).

University of Tokyo/Cal Poly

One of the highlights of the second day was

the live online demonstration by Yuya Nakamura (University of Tokyo) and Kyle Leveque (CalPoly) with XI-IV (sai-four), one of the successful Japanese CubeSats. XI-IV was launched in 2003 and is still fully operational, taking pictures and transmitting them to the ground stations.

The Team in Tokyo faces significant problems receiving signals from the satellites based on the bad frequency conditions in that city. Any pass below 10 degrees is useless for them. The Cal Poly ground station faces similar

challenges because of surrounding mountains and being located next to the School of Mechanical Engineering, which operates a lab with over 300 CAD workstations.

XI-IV takes pictures of the earth and, through ingenious pre-assessment of stored pictures, the ground station crew can focus on specific images for download purposes since XI-IV has no active attitude control system. For example, a quick spectral analysis of the picture by the satellite indicates the presence or absence of blue light (earth's ocean) and only these pictures are selected for download. Because of the download speed and the size of the pictures it currently takes two days for a single picture to be downloaded by the ground station. To shorten the timeframe, both schools developed a software/Internet-based approach to link various ground stations together.

Currently, CalPoly will start the download process and the University of Tokyo (UoT) will finish it, cutting the time down to seven hours. During the presentation, Yuya used an on-site computer during the presentation with a digital camera link to the ground station in Tokyo to initiate the download sequence as the satellite was just passing over Japan (see Figure 3). The live online demonstration was a big success and highly applauded by the workshop participants. Both, CalPoly and UoT are currently looking for other university based ground stations to join in the link and ultimately would like to involve selected ham operators with their satellite ground stations.

University of Hawaii

Tylor Tamishora and Dylan Ichikawa presented the University of Hawaii CubeSat program. They are in their fifth year and

have four CubeSat projects in various stages of development. The cube designs include using Garmin GPS systems, the Memsense Inertial Measurement Unit (IMU) Axis Foxboard CPU and Microhard MHX-2400 2.4G wireless modem, which they are changing from the ISM band to use amateur frequencies.

As a result of local site restrictions imposed by the University facilities department they are not able to set up a fixed satellite communication antenna system and have to rely on a mobile antenna set-up which they demonstrated in a video combined with a good sense of Hawaiian humor.

Industry Presentations

The Northrop Grumman representative, Hobson Lane, presented on the topic of attitude termination and control systems (ADCS) for satellites. Coming from a "big" satellite approach, he outlined important aspects and potential solutions for CubeSats, encouraging the community to actively seek new and innovative approaches to ADCS. For him, onboard attitude and ephemeris determination is one of the last hurdles required for CubeSats to achieve significant utility for a variety of commercial and scientific missions.

Thomas Chrien from the Raytheon Company focused on issues related to "Commercial-Off-the-Shelf" (COTS) cameras for satellite use. His presentation focused primarily on the Dalsa Piranha2 line scan camera (4096 lines).

Raytheon sees the big advantage of COTS cameras in their ability to be available immediately, if needed. They are flexible, often using well-established protocols (e.g. JPEG compression) and are affordable since they are mass-produced. Basic modifications for space use included staking screws and anchoring ribbon cables with epoxy and the use of syntactic foam for heat transfer and cushioning.

At the end of thermal, vibration and outgassing tests the team concluded that COTS cameras are appropriate for space provided the appropriate steps are taken and tests are run. Still, the concept is still considered try-by-fly.

Another industry perspective was given by Eric Tapio from Lockheed Martin. His presentation focused on the industrial perspective of CubeSats and their impact and benefit. Focusing on QuakeSat, he outlined some lessons learned and smart design solutions.



Larry Mortensen, representing Inland Northwest Space Alliance (INSA), introduced his organization and their goal, which is "Ad hoc coordination of Launch Opportunities for tertiary or secondary payloads only". His group is currently in the process of lobbying for government funding for a number of Minotaur rockets to launch educational payloads. The Minotaur is a modified Minuteman II ICBM (intercontinental ballistic missile) that uses the first two stages of the now-decommissioned Minuteman II and the upper two stages of the Pegasus XL booster. Although the program is of great interest to the community, no funding has been secured.

On the same topic, Dr. Rachel Leach from Space Access Technologies (SAT), provided an overview of their current approach to offer cost effective access to space for research and educational payloads. Unlike INSA, her organization has secured contracts and launches opportunities and is planning on brokering space on a number of different platforms including the Lockheed Martin Atlas 5, the Minotaur, Falcon 1 (Space X) and others. The current cost to launch a single 1kg CubeSat on Dnepr is \$40,000 and Space Access intends to hold that price point. Integration is through the CalPoly CubeSat program.

Unlike INSA, Space Access is designing and building "Ride Share Adapters" for a number of common spacecraft footprints including the Cal Poly P-Pod adapter. For the next launch on the Falcon 1, Space Access has 12 CubeSat spots available with nine already occupied. For more information refer to their Web site <http://www.access2space.com>.

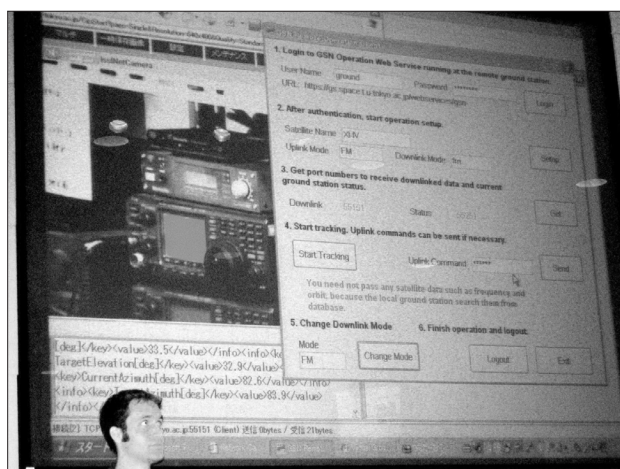


Figure 3: Online, live demonstration of an Internet link from CalPoly to the ground station at the University of Tokyo to initiate a downlink sequence for CubeSat XI-IV passing over Japan at the same time.

Rex Ridenoure talked about Ecliptic Enterprises Corporation, a company that brought live, on board rocket launch videos (RocketCam) to all of us. Their new product is the RocketPod, which shares the same external pod concept as the RocketCam. The external housing will hold an individual CubeSat and a single deployment system (POD). The slighter larger size in the launch POD allows the CubeSat to be a little longer, effectively giving the development team more space in a single cube. The advantage of this system is the short turn around. A CubeSat placed in the RocketPod can very quickly be mounted on the outside of a rocket for deployment. Test launches are planned on the next Falcon 1 rocket.

Pumpkin, Inc. had Andrew Kalman talk about making the most out of limited input/output pins available on current CubeSat microcontrollers. Through intelligent software writing and sequentially addressing onboard systems via a scheduler based on a Real Time Operating System (RTOS) the same pin on a microprocessor can be used for input and output signals.

AMSAT Presentations and Demonstrations

AMSAT Board member Emily Clarke, N1DID, gave an excellent talk on the history of AMSAT followed by information on current projects, tools and resources that are available to the CubeSat community through our organization. Emily did not hesitate to make the attendees aware of the fact that some of our members have some reservations about the use of amateur satellite frequencies for CubeSat and have expressed these through the AMSAT-BB. At the same time, Emily proposed that the CubeSat community

and AMSAT must cooperate to achieve common goals and encouraged the CubeSat community to actively engage AMSAT members and work with AMSAT.

Emily focused on the primary goals of improving the flow of information to assure the availability of information about CubeSat missions. She encouraged CubeSat builders to include useful and interesting Amateur Radio experiments on the CubeSats that can also be used to stimulate participation in K-12 science programs. Her open approach resulted

in numerous off-line discussions and several teams have requested assistance. An important follow-up was several portable satellite demonstrations that were well attended and observed with great interest.

It became very obvious to all of us representing AMSAT that the CubeSat community has a significant need for information and assistance and their interest in Amateur Radio and satellite communication will ultimately result in more licensed operators and potential members. The open and constructive approach displayed by our members at this workshop will go a long way in building relationships. At the same time AMSAT as an organization and the AMSAT Board in particular, need to consider how we can best assist CubeSat and other educational projects with a formal approach and formal recognition. This includes providing technical assistance and mentoring with clearly defined deliverables. AMSAT members also must recognize CubeSat project members can contribute to AMSAT's future growth.

Paul Shuch, N6TX, AMSAT Director for Education, presented a brief overview on the history of AMSAT's past educational involvement and talked about the new educational agenda for AMSAT. He used the opportunity to present a questionnaire to the participants seeking their interest to participate as educators. A number of participants responded positively and returned the questionnaire for follow-up.

Conclusion

Day 3 of the conference included a number of informal discussion tracks covering communication, power, integration and testing, attitude determination and others. Primarily focused on interactive discussion, the participants shared their experiences and addressed open questions. This was a great learning experience for the new groups just starting out in a CubeSat project.

The 2006 3rd CalPoly CubeSat workshop was a great success and we are certainly looking forward to the next one. For those of you, who would like to learn more about CubeSat projects, please refer to our AMSAT Web site and the listing of current and upcoming projects.

Feel free to contact Stefan (VE4NSA@amsat.org) or Emily (N1DID@amsat.org) for additional information. ☺



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The Radio Amateur Satellite Corporation (AMSAT or AMSAT-NA) is a non-profit scientific and educational organization chartered in Washington, DC, in 1969. Since then, AMSAT and colleague organizations around the world have built over 50 ham radio satellites. 15 of these satellites continue in operation.

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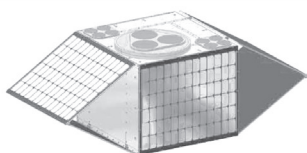


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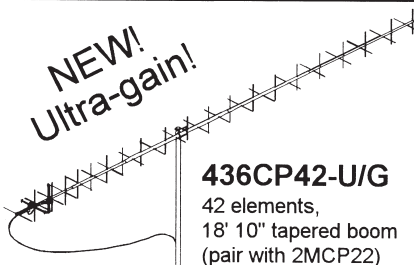
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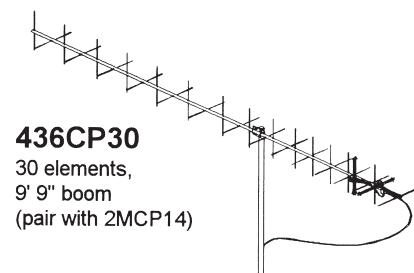
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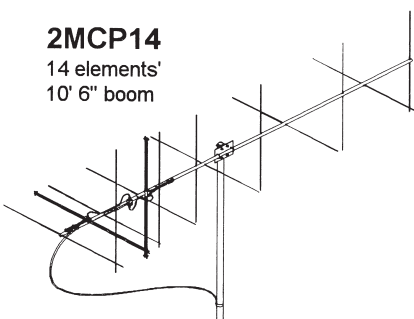
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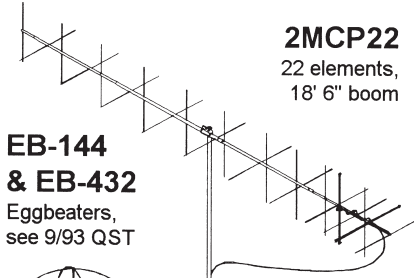
436CP30

30 elements,
9' 9" boom
(pair with 2MCP14)



2MCP14

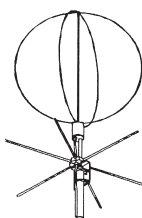
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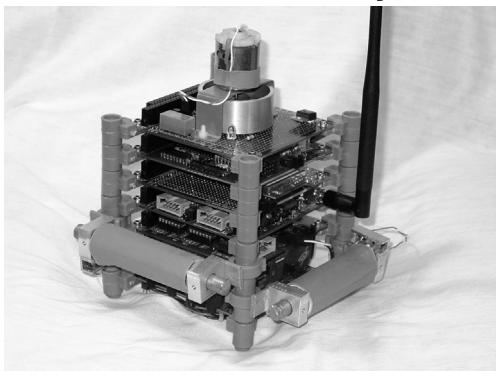
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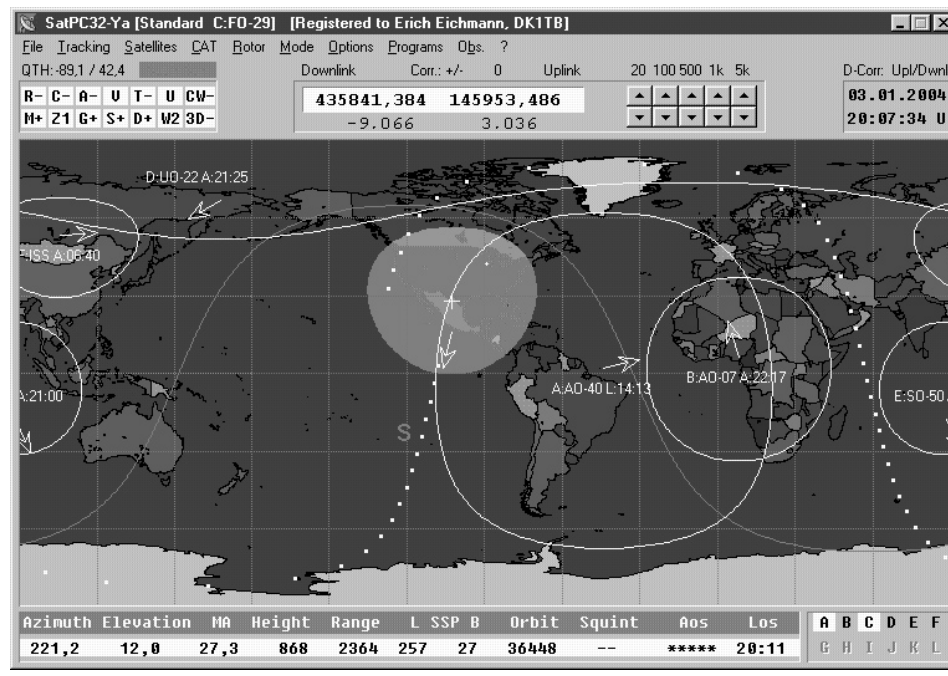
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Satellite Signals and Reception, Part II

by Gould Smith, WA4SXM, wa4sxm@amsat.org

In Part I we talked about the signal loss from the satellite to the ground station and how this is measured in dB. In working on the second part I discovered that there are a number of important issues to discuss about the satellite downlink signal. So, I am breaking the signal path into smaller increments and cover these additional things that affect satellite signals. The original two-part column is now a four-part column. Part II will deal with the effect of the satellite orbit on the reception characteristics. Part III will be on satellite antennas and Part IV will cover preamps and coax.

from South to North) and the point furthest from the earth is about 58° S latitude around Antarctica (both ascending and descending nodes). Many of the drawings of satellite passes show the satellite pass as an arc of a circle, so this tends to reinforce this idea. The actual pass is more of an arc from an ellipse, much further at the beginning and end of the pass and closest at mid pass. In Figure 1 you can see that the distance (Range) of AO-51 on this 33° pass is actually 1154 km from my QTH around mid pass and the closest it will get this pass. If you go back to when the pass first appeared above my horizon it

was about 3200 km away!

AO-51 Ranges

Being a very visual learner, I graphed the ranges from a representative sample of AO-51 passes to see how they changed. Figure 2 shows the range arc and the incredible range changes that take place during passes with different maximum elevations. You can see that all the passes start at a range of about 3200 km (at my location), but the 11° pass doesn't get any closer than about 2300 km. The 79° pass comes close to the actual height of the satellite above ground (during mid pass), but the range quickly increases again. At TCA (Time Closest Approach, mid pass) for a 44° pass the satellite is 2200 km closer than when the satellite first appeared. It becomes evident that the lower the maximum elevation of the pass, the further the satellite is from you during the pass and therefore more path loss. The fact that you are actually slanting through more atmosphere, gives you additional atmospheric signal loss. Also note that the higher the elevation, the longer the pass lasts, up to about 44° when there is little change in the length of the pass.

So the point is that you will have a weaker signal to deal with than you may have calculated.

Path Loss

Using the path loss calculations we covered in Part I, Table 1 shows that the 435 MHz signal from AO-51 is 9dB weaker at 3200 km than at 1154 km. The TCA for a 44° pass is 11 dB stronger than when the satellite first appears. Well it turns out that the lower the maximum elevation of the pass, the further

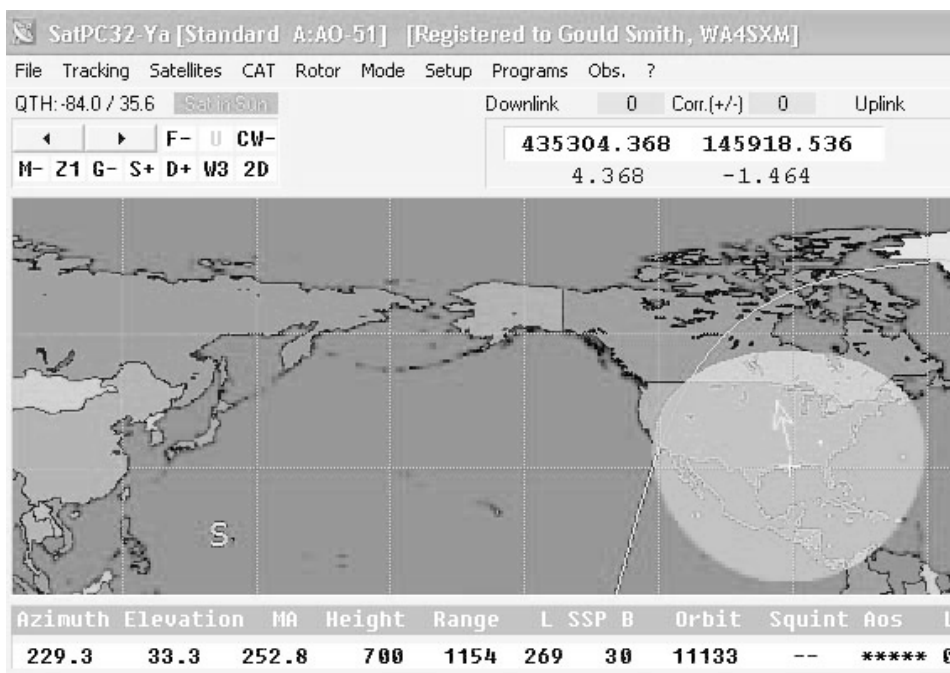


Figure 1: SatPC32 Height, Range and SSP for AO-51.

LEO Orbits

You know that the altitude of the satellite is the height above the average terrain at the SSP (Sub Satellite Point), see Figure 1. If you draw a line between the satellite and the center of the earth, the place that the line intersects the surface of the earth is the SSP. The footprint of the satellite expands from this point, depending upon the height of the satellite. Sun synchronous LEO satellites tend to have a circular orbit, so it is easy to think of the height as the distance to the satellite. Using *InstantTrack* or *SatPC32* in fast forward/preview mode you can see that the height of AO-51 varies between 700 km and 835 km. The closest point is about 30° N latitude on the ascending node (going

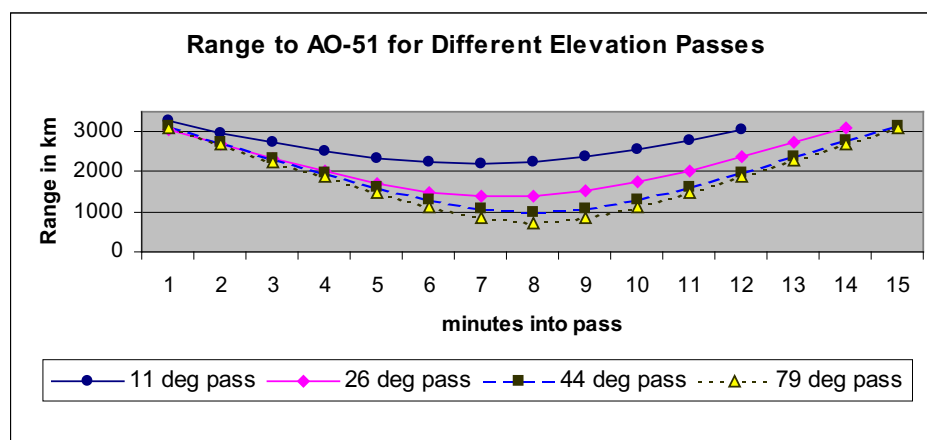


Figure 2: Graph of AO-51 ranges at various maximum elevations.



Range (km)	dB Loss	Part of the Pass
3200	155	AOS, LOS
2300	152	TCA 11° pass
1400	148	TCA 26° pass
1154	146	TCA 33° pass
1000	145	TCA 44° pass
800	143	TCA 79° pass

Table 1: AO-51 435 MHz Path Loss.

the satellite is from you during the pass and therefore more path loss. Looking at it the opposite way, the higher the maximum elevation, the stronger the signal will be at TCA. For an 80° pass this is a 12 dB increase

(or 16 times stronger than AOS). So, you are most likely to hear the satellite at mid pass with a poor antenna, and less likely to hear it before or after.

Maximum Elevations

Wondering what the actual pass coverage was like for me at 36° latitude, I decided to find out. Using *InstantTrack*, I created a file of six months worth of passes for my location, then imported that into Excel and ran a pivot table to get the pass breakdown. Figure 3 is a bar graph of these AO-51 passes; this includes more than a thousand passes. It is quite obvious that the majority of passes for people in the mid latitudes are low maximum elevation ones.

The next question was exactly how low. So I grouped the passes into 10° elevation ranges and did a pie chart. This data is shown in Figure 4, and is exclusive for the ranges.

So, if you add all of the passes from 0 to 39 degrees maximum elevation you have 74% of all the passes at my QTH. Sixty-five percent of the total passes have a maximum elevation between 0° and 29°. If you can't work the very low passes, 0°- 9° then one of every three passes you can not use. On the other hand 70% of all the passes are good for you. Those really low passes, where the satellite just skirts the horizon between 0° and 5°, account for 19% of all passes.

I now have another project on my list – “Does your latitude/longitude affect the breakdown on passes?” Next time we will talk about the final chains in the link of getting these weak signals from the satellite to your radio. I will address issues such as: What are the pros and cons of different satellite antennas? Why a preamp at the antenna is a great idea and things to consider in selecting coax. 📡

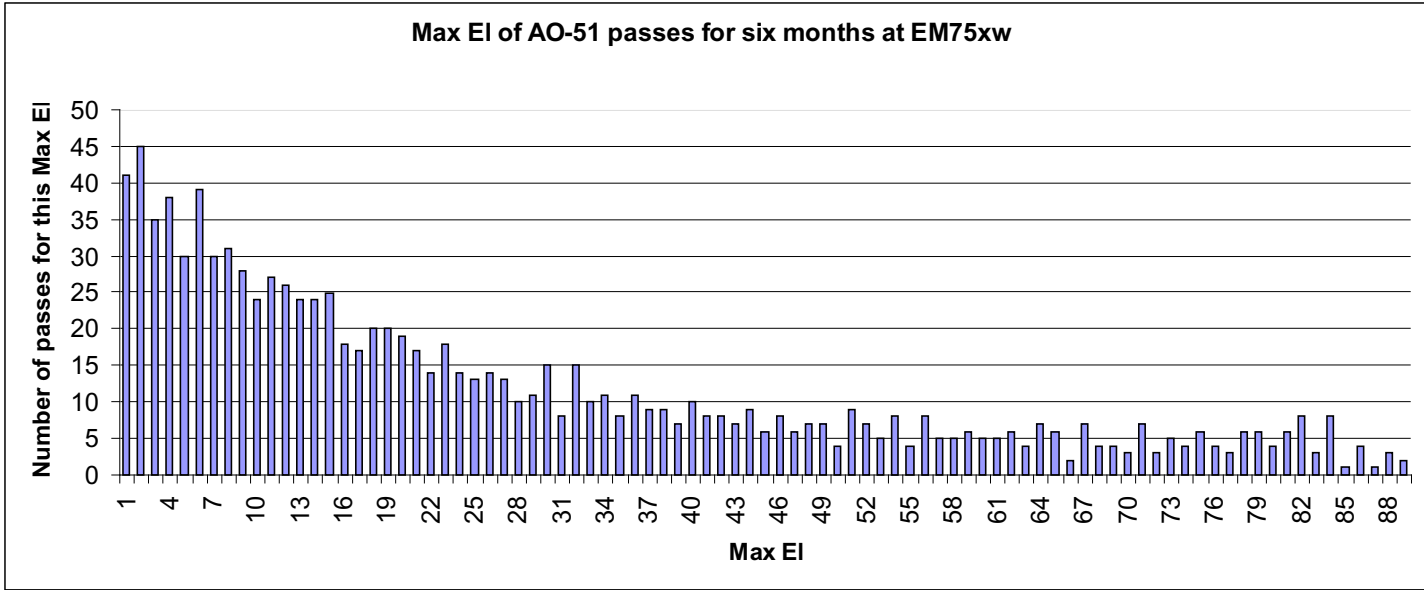
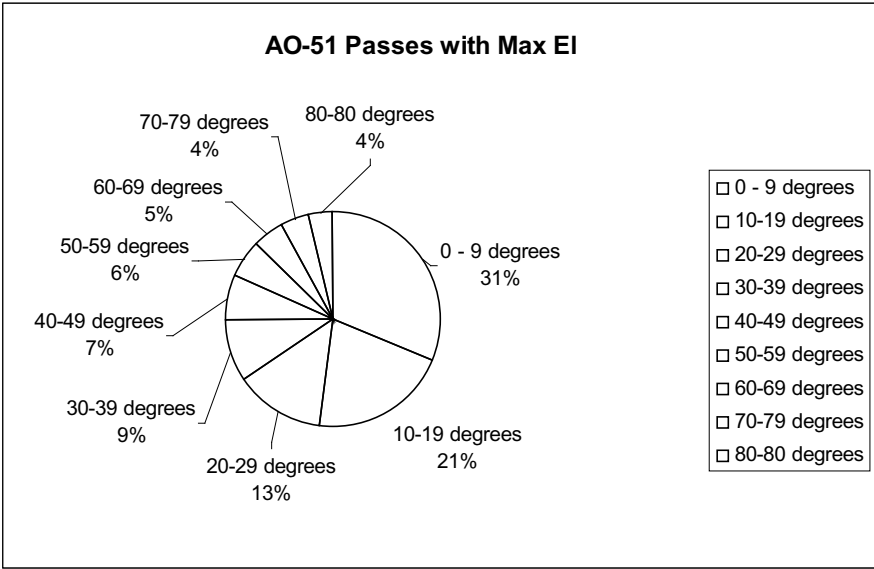


Figure 3: AO-51 Maximum Elevation Pass Breakdown.

Figure 4: AO-51 passes by groups.



The Orbital Classroom “Reinventing The Cube”

© 2006 by Dr. H. Paul Shuch, N6TX, n6tx@amsat.org, AMSAT Director of Education



The Orbital Classroom

In a previous column, we introduced CubeSats, the cheap and easy way to involve students in the design, construction, launch and operation of ham satellites. In case you missed that minor opus, a CubeSat is a 1 kg picosat in a standardized cubic form factor, 10 cm on a side, designed for cluster launch from a wide range of boosters, into any orbit of convenience. So far, the cubes have all ended up in Low Earth Orbit (LEO), where minimal path loss makes their signals simple to copy with modest 2 meter or 70 cm equipment. In this installment, we will introduce a unique science mission that lends itself perfectly to CubeSat support. If your 1 kg picosat project is a solution in search of a problem, have we got a deal for you!

Although the world's navies are in fact involved in satellite technology, it should surprise nobody that their primary mission involves ocean-going vessels. They also engage in oceanographic research. In addition to training the next generation of naval officers, the US Naval Academy in Annapolis, MD is involved in such research, and much of it makes use of satellite technology.

One of the projects in which Annapolis midshipmen participate is the deployment of ocean-going buoys for monitoring ocean levels, currents, temperatures, salinity and composition. Once built and cast adrift on the sea, these buoys have to transmit their data to – somewhere. And that's where CubeSats can come in.

Bob Bruninga, WB4APR, heads up the US Naval Academy Satellite Lab. He is also well known to the Amateur Radio community as the father of APRS® (Automatic Position Reporting System), a technology that marries packet radio digipeaters to GPS, for the purpose of tracking moving vehicles (including your mobile 2 meter station). Why not, suggests Bob, use APRS and CubeSats together, to keep track of his students' ocean buoys, and perhaps to collect their scientific data via store-and-forward packet technology?

“For CubeSat missions looking for a neat project,” writes Bruninga, “remember, we welcome more low duty cycle packet digital devices on the global satellite packet uplink frequency of 145.825 MHz. The more small

satellites providing a bent-pipe relay on this frequency, the better the connectivity for other student school projects, such as ocean buoys, environmental sensors, arctic weather stations, and wilderness explorers using APRS.”

I floated Bob's suggestion (OK, guilty as charged ...) at a recent CubeSat workshop at the California Polytechnic University, to a generally favorable response. Most enthusiastic, not surprisingly, were those radio amateurs at the workshop who see packet satellites as a useful augmentation to their own Amateur Radio pursuits. This is altogether appropriate, but let's not lose sight of the educational opportunity with which the proposal presents us. The students building the buoys may have no particular interest in ham radio, let alone APRS, as an end unto itself. Is there an opportunity here to turn them on to Amateur Radio, amateur satellites, and AMSAT? Before we dismiss as non-ham these scientific or educational projects of our fellow radio amateurs, we should remember that broadening the appeal of Amateur Radio benefits us all.

Of course, the proposed satellites, and their global satellite data channel, are not limited to ocean buoys. Once operational, they can be used by any remote environmental sensor (or any other remote Amateur Radio device) that needs to have low duty-cycle communications. Those interested in learning more about US Naval Academy buoys, and related projects, may wish to browse WB4APR's Web page at <http://www.ew.usna.edu/~bruninga/buoy.html>. If you're involved with a CubeSat project, as a faculty advisor, mentor, or student, you might wish to consider reinventing your cube in support of these worthy efforts.

CubeSats are not the only birds proposed for packet digipeating applications, nor are they the only such options being supported at the US Naval Academy. Bob Bruninga's students were also responsible for the deployment of PCSAT2, a 145.825 MHz AX.25 digipeater attached to the International Space Station. Although never assigned an OSCAR designation because it is an appendage on another spacecraft (the ISS), similar payloads can easily be made stand-alone (fly-alone?) in the future and would thus be eligible to become true OSCAR satellites. Imagine a

sky full of orbital 2-meter digipeaters, just waiting to relay your packets around the world and you'll get some idea of where this Naval Academy initiative might some day take us.

Both the packet transponder on PCSAT2 and the ARISS ham radio on the ISS can already relay some of these data experiments, and they are both visible on the Web via the following links:

<http://www.ariss.net>

<http://www.findu.com/cgi-bin/pcsat2.cgi>

If you're new to CubeSats and want to learn more, you should take a look at the CubeSat Web site hosted by Cal Poly, at <http://www.cubesat.org>. There you'll find the CubeSat electrical and mechanical specifications, information about many of the existing and planned cube projects, and a good overview of using satellites in education.

To copy a CubeSat, take a look at the satellite database on the AMSAT Web site. It lists operational status, frequencies and modes for all those cubes that have been granted OSCAR designations. Several of the cubes downlink easily copyable CW telemetry in the 435 – 438 MHz satellite downlink band. You'll be amazed at how loud ½ watt of RF can be from LEO, even into an omnidirectional antenna.

A few cubes transmit FM voice or SSTV and are equally easy to copy. Other cubes transmit 1200 baud or 9600 baud ASCII. These modes take a bit more link margin to decode, generally requiring a small beam. The popular Arrow 2 meter / 70 cm Yagi combo works quite well on these birds, as it does on our various other Mode B or Mode J LEO ham satellites. Two line Keplerian elements, available from all the usual sources, will let you track CubeSats with your favorite AMSAT software.

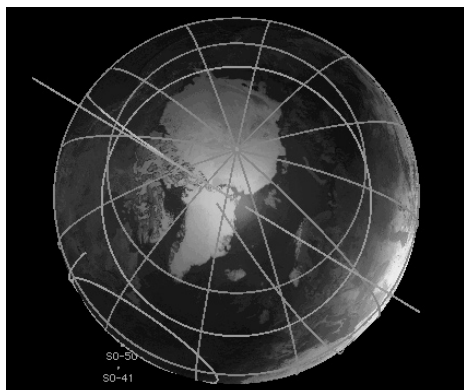
There's no denying that talking to other hams via a relay satellite is an important part of ham radio. But don't overlook the simple pleasures of intercepting these abundant signals from space. This is a good way to introduce students, civic groups, and your next-door neighbor to the joys of Amateur Radio. Many new hams got their start by looking up and listening. ☺

See photograph on page 15.



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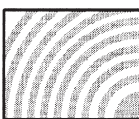
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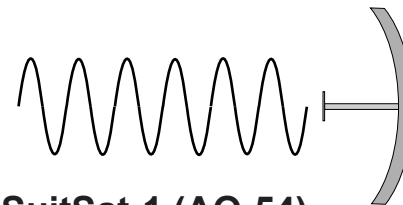
The Florida AMSAT Net becoming a popular Thursday evening event. by David Jordan, AA4KN, aa4kn@amsat.org

Since the initial meeting of the Florida AMSAT Net on March 30, 2006, it is becoming the place to be on Thursday evenings for many amateurs with an enthusiasm for learning more about what's up there in terms of amateur satellites and how best to use them. The net meets every Thursday evening from 19:30 to 20:30 ET or 23:30 to 00:30 UTC. The net was initially conceived and is currently hosted by Drew, KO4MA, Dave, AA4KN, or Robert, KI4HXT, as a way of sharing current amateur satellite related news, answering questions for newcomers or seasoned operators and generally staying in touch with hams they've met at local Florida hamfests.

Using multiple service links, the net can now provide worldwide access to all amateurs. The net is currently carried by the N4HHA UHF repeater in Orlando on 443.1 MHz +103.5 PL which is linked with the West Central Florida Group, Inc. NI4CE system of multiple repeaters providing coverage over all or parts of 12 Florida counties (see www.ni4ce.org for repeaters and frequencies). In addition, broadcasts are available to the central Florida east coast area through the N4LEM repeater on 147.36 MHz +107.2 PL.

Access to the net can also be achieved through EchoLink. Amateurs with valid registrations can find the net by linking to KG4YZY-R at node 4429. Details concerning EchoLink can be found at www.echolink.org.

The net format generally consists of announcements, discussion and bulletins while also hosting check-ins and their comments. Much of the design and integration of our satellites takes place in the central Florida area. Therefore, the net offers, on many occasions, opportunities for amateurs to hear first hand reports from the individuals involved in the development of amateur satellites and the chance to enter into discussion with them on their progress. Two of our regular local check-ins are AMSAT VP Lee, KU4OS, and AMSAT Lab manager and BOD member Lou, W5DID. When possible, the net tries to have a topic of discussion concerning some aspect of the hobby which, for instance, may relate to operation of personal ham equipment or how to better access a particular satellite, etc. All amateurs are invited to become part of this weekly event and any questions concerning the net can be sent to aa4kn@amsat.org, ko4ma@amsat.org, ki4hxt@amsat.org or ku4os@amsat.org.



SuitSat-1 (AO-54) Re-Enters Earth's Atmosphere

SuitSat-1 (AO-54) is history. The surplus Russian Orlan spacesuit turned satellite re-entered and burned up in Earth's atmosphere Thursday, September 7, at 1600 UTC some 1400 km south-southwest of Western Australia. The announcement came September 8 from Amateur Radio on the International Space Station (ARISS) International Chairman Frank Bauer, KA3HDO. SuitSat-1 became one of the greatest public relations vehicles for Amateur Radio in years. Bauer expressed thanks to "all who made SuitSat-1 the phenomenal event that it was." Launched February 3 during a spacewalk from the ISS, SuitSat-1 was heard around the world, although at a much weaker signal strength than anticipated.

"Your hard work and dedication paid off," Bauer continued. "In just three weeks the SuitSat team developed and delivered a safe satellite system that has gained the confidence of the international space agencies." Bauer also noted the "unprecedented press coverage" that included more than 9 million hits on the SuitSat-1 Web site, www.suitsat.org, during February alone as well as several prominent mentions in the general news media.

"Students around the world had the opportunity to participate in a seven-month 'school spacewalk' with the artwork, pictures, signatures and voices onboard," Bauer pointed out. "And the 'super-sleuth' ham radio operators extraordinaire were able to pull a significant amount of data from the satellite, despite its low signal strength."

After SuitSat-1's VHF ham radio payload stopped transmitting earlier this year, AMSAT initiated a "Chicken Little Contest," for participants to guess when SuitSat-1 would de-orbit. Winners and more information are on the AMSAT Web site, www.amsat.org/amsat-new/ariss/suitsatContest.php.

Bauer said plans for a potential SuitSat-2 will be a discussion topic at the AMSAT/ARISS joint meeting in October.



The Orbital Classroom

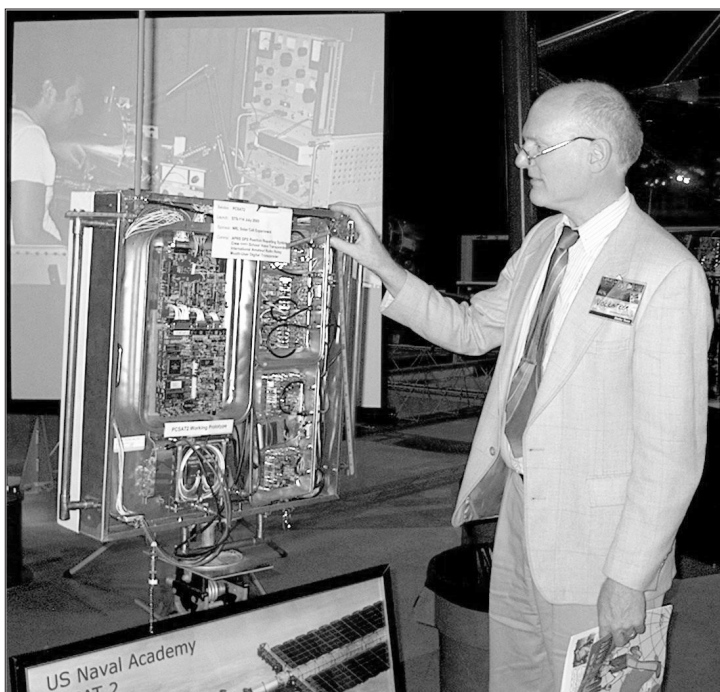


Photo 1: Bob Bruninga, WB4APR, showing off the US Naval Academy's PCSAT2 engineering prototype at Space Day at the National Air and Space Museum in May 2006.



Between a Rock and Outer Space: Interview with OSCAR Pioneer Lance Ginner

Interviewed by David Hartzell, NØTGD, hartzell@gmail.com, Project OSCAR

Recently, I sat down with Lance Ginner, K6GSJ, one of the original Project OSCAR members who helped design and fly the first amateur satellites. Overlooking Silicon Valley from his house in the Portola Valley hills of Northern California, we discussed the amazing set of events that defined the early days of amateur satellites. Over forty years ago, a unique set of individuals, Lockheed, the United States Air Force and the national security needs of the United States contributed to the successful launching of the amateur satellite community, which thrives today in many forms. Here is Lance's story.

NØTGD: How did you get involved with Project OSCAR?

K6GSJ: I started work at Lockheed Missiles and Space Company in Sunnyvale, CA in January 1960 as an "A" Technician. I was 21 years old. I worked in the Agena A and B space vehicle checkout complex and I was initially responsible for designing and building test aids to facilitate final systems checkout of the satellite prior to its shipment to Vandenberg Air Force Base for launch.

The following year I went to a salaried position and was a test conductor in satellite subsystems and systems level checkout. It was at this time I became aware of Project OSCAR through Chuck Townes, K6LFH, (SK) and Nick Marshall, W6OLO, (SK), both of whom worked at Lockheed.

My career at Lockheed for the next five years or so was primarily in the area of satellite systems checkout for a variety of space vehicles following the Discoverer series of satellites. I then moved more into the payload and classified program areas in more of an engineering capacity.

NØTGD: How did you contribute to the various OSCARs launched?

K6GSJ: I was directly involved in OSCAR 1 through 8 in one capacity or another. Chuck Smallhouse, W6MGZ, and Al Diem designed and built the transmitters for both OSCAR 1 and 2. Ed Beck, K6ZX, designed the "hi" keyer. I took the RF and keyer modules and did the internal satellite wiring to the batteries and deployment switch. As part of my normal duties at Lockheed, I was able to see the integration of the OSCAR 1 satellite with the Discoverer 36 Agena B satellite.

I worked with Nick Marshall in the qualification of the OSCAR 1 satellite. We performed vibration, shock and temperature testing of the satellite "after hours" at the Lockheed Palo Alto Research Laboratories. OSCAR 1 was launched on December 12, 1961, being the first stand-alone "sub-satellite" that was deployed from a larger spacecraft in orbit. OSCAR 2 was launched only six months later on Discoverer 43.

NØTGD: In your mind, what were the most challenging aspects of the first few OSCARs?

K6GSJ: Getting the early OSCAR satellites approved for launch was a highly political process. I was a 21 year-old just starting out in the field and was tremendously impressed by the talents of the OSCAR Board of Directors. The challenges the board faced in obtaining the permissions from the various government agencies and Lockheed were enormous. We had to keep in mind that ejectable sub-satellites were unknown at this time, and convincing the various agencies that this "honor" should go to a "home built" satellite with no official credentials was seen as a big risk. A premature release of the OSCAR satellite would keep the Agena satellite from deploying its booster adapter and would be a catastrophic end to the main mission. There were numerous meetings with government and military representatives (including many well-connected hams). These discussions and the creation of the OSCAR "White Paper" helped establish the political and technical credibility we needed to obtain launch permission. The bureaucratic efforts probably exceeded those required to build the satellite.

There were certainly technical risks in the space hardware. In 1961, there were no transistors that would put out any real power at 144 MHz. We ended up using a prototype Fairchild part that was not even on the market. In those days, you did not have someone saying, "you can't do it that way", because no one had ever done it before!

After the launch of OSCAR 2, there was long period of trying to decide what to do next. The concept of a translator satellite (OSCAR 3) was developed by Ed Hilton, W6VKP, (SK) and Don Norgaard, W6VMH, (SK). The production of an in-band 2-meter linear translator (including antennas) in a shoebox-

sized container was a very tough technical challenge. Again we were confronted by the lack of adequate RF components that operated at 144 MHz and that could provide the tight filtering that was required to minimize desensitization between the input and output frequencies.

We had a launch opportunity in March 1965 on a classified mission, which made it a challenge to interface with the rest of the OSCAR group and builders as I was the only one in the organization with the proper security clearances. We designed a new satellite structure to take advantage of more available space and the unique mounting and ejection structure. Solar arrays were not available in any quantity and we had to go to a space-qualified silver-zinc primary battery for power. I hand carried OSCAR 3 in my car to Vandenberg Air Force Base and assisted with the mounting of it to the main spacecraft.

I think OSCAR 3 was the high point of my OSCAR experience because I was almost solely responsible for the design of the satellite enclosure, ejection mechanism and launch coordination. The electronics design and construction efforts of Ed Hilton and Don Norgaard were truly state of the art at the time. I learned a great deal from both of them.

NØTGD: I'm sure things didn't always go as planned. What didn't go right?

K6GSJ: At the time of the OSCAR 3 launch, I was in charge of a small "off the books" tracking station that we had about a mile away from the main Lockheed facility. We had a 17-foot dish on a WWII SCR-584 radar pedestal along with a small command link antenna off the side of the dish. I was monitoring the countdown and launch activities. The launch date/time were classified but the Project OSCAR group needed to be prepared. I set up several launch rehearsals beforehand to allow Project OSCAR to establish the communications paths to disseminate information to the ham community regarding orbit and tracking information for OSCAR 3. It just so happened that one of these rehearsals turned out to coincide with the actual launch on March 9, 1965. While observing the launch from the small tracking station and listening to the launch commentary, we got a report





that the deployment switch for the OSCAR 3 satellite showed “deployed”. If this were true, then the entire mission was going to fail as the OSCAR would wedge between the Agena space vehicle and the booster adapter and keep it from separating and performing the final rocket burn to orbit.

The next few minutes were the worst of my life. If the telemetry was correct then that would be last of the OSCAR program (and probably my career as well) as I had designed the deployment mechanism and “certified” the spacecraft was qualified. Fortunately the separation was successful and later investigation found that the separation indicator switch on the Agena side of the interface had been misadjusted prior to launch.

Then there was OSCAR 4, a Phase III bird intended to be in a geosynchronous orbit, but the third stage of the Titan 4 didn’t fire. This put the third stage with seven other payloads, including OSCAR 4, into an elliptical high-earth orbit. The resulting 22,000 x 100 mile, 9.5 hour orbit was totally unexpected. We were fortunate in that Amateur Radio operators did acquire the OSCAR 4 signal. Based on the orbit period, we were able to construct user visibility projections by using a large Earth globe and stiff wire scaled elliptical loop that was representative of the orbit. Masking tape markers were placed at approximate hourly orbital time intervals and an alligator clip was used to indicate the position of the satellite on the orbital loop. By standing on a tall stepladder, looking from behind the alligator clip towards the globe, we could “eyeball” the relative position on the globe based on multiple ham operator signal acquisition and loss times. For the first 24 hours or so the Air Force and various other payload vendors would call us to get an estimate of where their satellites were. We were fortunate in having a wide observer base and the ability to quickly react to unusual circumstances. *[Just another case where Amateur Radio has added value to the larger community. What a fantastic bit of information! - Ed.]*

The TRW radio club in Los Angeles built OSCAR 4. I was involved in the launch coordination with TRW and the Titan 4 contractor. The story of how OSCAR 4 got the opportunity for a ride to synchronous orbit is a classic. The Titan IIIC launch system was just being qualified and the press had been having a field day when they found out that the boosters were being tested with

a payload of sand to qualify the booster lift capability. What made it even worse was that it was not even Florida’s sand, but for some reason had to be imported from out-of-state!

Embarrassed, the Air Force put out a plea for payloads they could fly as part of the test series. While the risk to payloads was high, as the Titan system was still in development, there were many organizations including Project OSCAR that wanted to take advantage of the opportunity. The problem we had was that we were given less than a year to design, test and integrate a suitable ham satellite. OSCAR 3 was in its final testing phases and fortunately, at this time the TRW radio club came to the rescue. They were able to put together a satellite using “spare” parts and solar panels from other missions.

NØTGD: Were you familiar with the primary payload of the Discoverer missions?

K6GSJ: Yes, I was familiar with the primary payload, as it was my day job. We (Lockheed) were building and launching the first ever spy satellites known as CORONA and OSCAR was along for the ride.

The recovery of the CORONA film capsules was still a significant technical challenge at the launch of Vehicle 1119 (Discoverer 36). Once we established technical credibility with the successful launch of OSCAR 1 and 2, subsequent Air Force launch efforts were much easier. I was fortunate to have the security clearances necessary to facilitate integration of later OSCARs with more classified launches.

There is a very good book that describes the history of the Corona spy satellites that I would encourage anyone to read: *Eye in the Sky: The Story of the Corona Spy Satellites*, edited by Dwayne A. Day, John M Logsdon and Brian Latell.

NØTGD: Did you think that an organization like AMSAT would evolve out of your early efforts?

K6GSJ: OSCAR activity slowed after a very active five years (1960-1965) and the launch of four satellites. During this time, a group from Australia wrote to us asking for assistance in building their satellite. I provided design guidance with regard to the space-frame “envelope” based on the possibility of another launch opportunity similar to OSCAR 3. The Australians did deliver a satellite, which became OSCAR 5. We did not have another launch opportunity

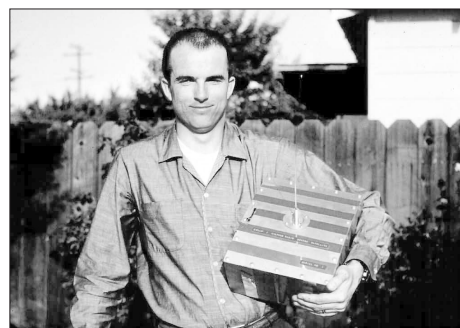
and the satellite went into storage.

It was then I met Jan King, W3GEY, along with Perry Klein, W3PK, Dick Daniels, W4PUJ, and many others from the then-developing AMSAT organization. AMSAT spearheaded the ultimately successful drive to find a NASA launch opportunity for the OSCAR 5 satellite. Jan, in concert with the Australians, brought the satellite up to launch readiness for a successful flight on January 23, 1979. I had enormous respect for Jan’s talents and dedication. It was very clear then that AMSAT would be successful. Project OSCAR then provided space-quality parts and some space frame and equipment enclosures for several of the early AMSAT spacecraft.

I have wonderful memories of the early years and relish having met such talented and dedicated people in the Project OSCAR and AMSAT organizations.

NØTGD: Lance, thanks for your time. I know many others will appreciate and enjoy reading about your experiences with the early days. 73!

Interviewer’s Notes: *In the late 1990s, President Bill Clinton declassified the CORONA intelligence gathering program, including technical material and over 900,000 photos. CORONA and its follow-on programs helped close the perceived missile gap during the cold war with the Soviet Union. It also helped establish the precedence and technology needed for various forms of space-based earth monitoring, and OSCAR was along for the ride. After Project OSCAR, Lance became involved with the deployment of FM repeaters in the Bay Area, moving into microwave experimentation. He retired from Lockheed in 1996 after a long, distinguished career working on various space-related projects. Don’t miss your chance to meet or become reacquainted with Lance at this year’s AMSAT Symposium, being held in the San Francisco Bay Area this October. See www.amsat.org for more details.* ☺



Lance Ginner, K6GSJ, holding OSCAR 1.



The ARISS HF Antenna

by Lou McFadin, W5DID, w5did@amsat.org, ARISS U.S. Hardware Manager

There have been several inquiries as to when the HF system will become operational on ISS. One important step is to get an HF radio on board. This is still being worked. Another item that needs to be addressed is the suitability of the current HF antenna on ISS to support HF operations. Since the HF antenna was initially built and installed, the ARISS team has learned some

Current ISS HF Antenna

The HF antenna on ISS was designed based on specifications from the ARISS international team as well as everyone's best understanding of the properties of the Service Module. This design was based on the assumption that a good ground plane would be available when the antenna was mounted on the exterior of the Service

It is a basic tenet of antenna design that a quarter wave whip antenna needs a ground plane to function properly. After many discussions of how to run a valid test of the flight configuration antennas in a ground based test, it was decided that the best simulation we could achieve within our limited resources (since there wasn't a Russian Service Module available that could adequately simulate flight conditions) was to mount a flight configuration antenna on an insulated platform about 3 feet from a ground plane. This was accomplished by using a wooden stool about 3 feet tall.

As was expected the SWR as measured by an MFJ-269 antenna analyzer indicated the SWR was greater than 31:1 at all the amateur HF band frequencies.

The amateur HF frequencies allowed for space operations are:

7.000	-	7.100 MHz
14.000	-	14.250 MHz
(That's right, 250 not 350.)		
18.068	-	18.168 MHz
21.000	-	21.450 MHz
24.890	-	24.990 MHz
28.000	-	29.700 MHz

It was then decided to see what could be done to lower the SWR on at least one band where transmission is allowed from space to ground. A new EVA suitable element was designed that could be installed in the spare antenna hole on the WA4 (HF) antenna on ISS. This hole is a 5/8-24 threaded hole that will accept a type N barrel connector. It is between the 2.5-meter tape element and the handle.

This element is also a measuring tape of the same type used in the original antenna. It is designed to fit into the existing hole and then be tightened in place with a turn of the knob.

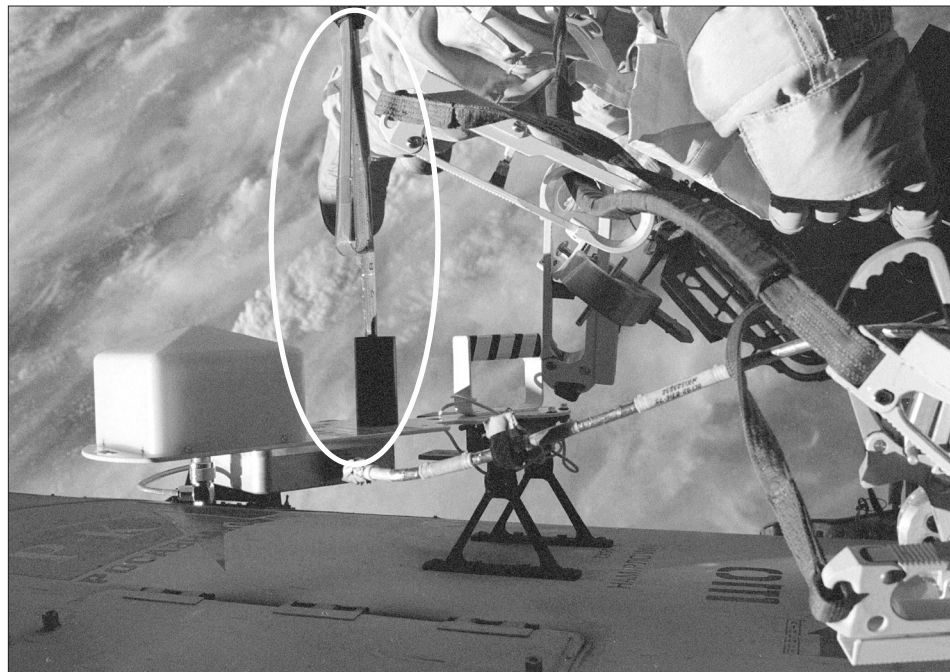


Photo 1: The HF antenna mounted on an ISS handrail.

subtle aspects of the Service Module (where the HF antenna is installed) and mounting that call into question the efficiency of the current design. With this new data, the ARISS team now knows what needs to be done to make it fully operational. This article discusses the current antenna and proposes how to get it ready for use.

Module. Prior to the delivery and flight of the HF antenna, the ARISS team was not able to perform a test of the flight configuration, as the Service Module was unavailable for our testing prior to flight. So the opportunity to perform that all-important End-to-End test was missed.

As the ARISS team has obtained more information on the Service Module and we were able to perform some very limited tests in a Service Module simulator in Russia, we have learned that the assumptions used to design and install the antenna led to a sub-optimal design. Of particular note is the fact that the portion of the Service Module where the ISS-HAM antennas are mounted is a non-metallic cylindrical ring with the antennas mounted on handrails with a hard anodized (insulating) finish. To add to the problem, the clamp that holds the antenna to the handrail has a hard anodized finish. The result is that the ISS-HAM HF antenna has no ground plane.

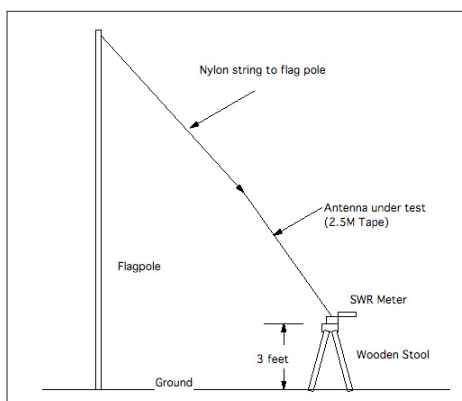


Figure 1: Antenna test arrangement.



Photo 2: The HF antenna structure uses a measuring tape as its radiating element.



Photo 3: The additional element can be installed using one hand by tightening the knob.

It can be done with one hand. The length of the tape was adjusted by trimming it until the resonant frequency was 28.205 MHz. Further trimming brought the frequency to the middle of the band at 28.6 MHz.

During testing care was taken to keep the angle between the elements at 90 degrees for all tests. See Photo 5.

Additional tests were run both with and without the extra element with a long fifty-foot length of 9913 cable, which is similar in characteristics and length to the cable on the ISS. The results were the same no matter how the cable was laid out.

Conclusions

1. The HF antenna as currently configured on the ISS is not suitable for transmitting on HF.
2. The problem can be corrected by adding one element forming a V antenna.
3. The correction is only good for one HF band for transmission. The other bands can be used for reception at reduced efficiency.
4. The layout of cable doesn't matter nor does it help correct the problem. 📶



Photo 6: The author with the test setup.



Photo 4: The additional element was trimmed until the resonant frequency was 28.205 MHz.



Photo 5: Care was taken to maintain the elements at 90 degrees to each other.

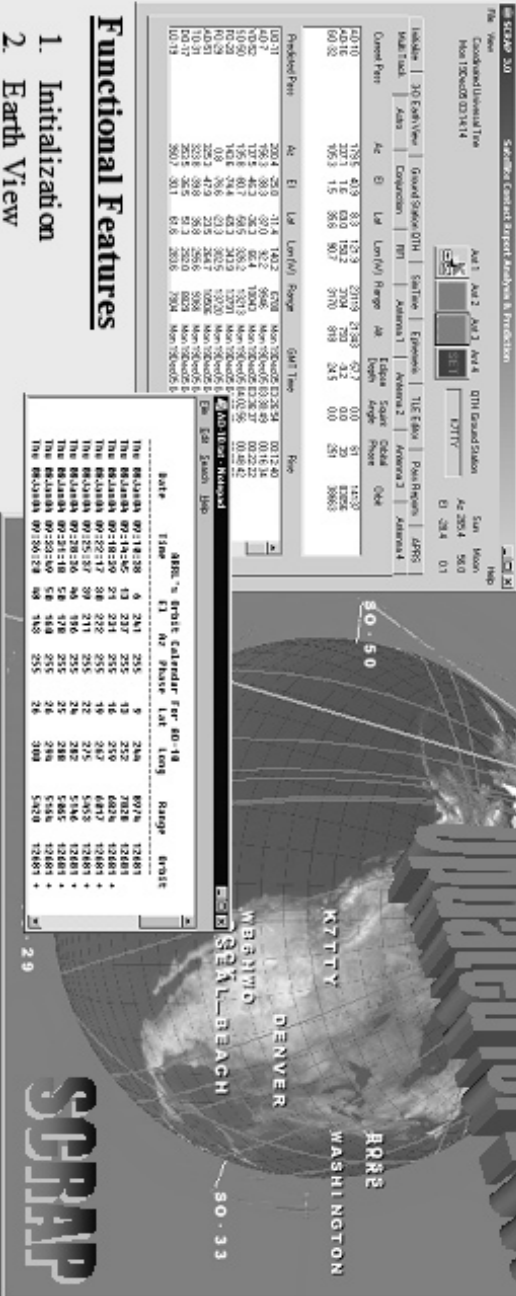
Table 1: SWR for various frequencies with the "ground plane" element added.

With Extra Element (98")			
Frequency (MHz)	SWR	X(R)	X(Z)
28.6	1.1	47	0
28	1.2	38	17
28.2	1.3	42	10
28.4	1.1	44	3
28.6	1	47	0
28.8	1.1	52	8
21.2	>31	2	167
24.9	12.7	3	94
18.1	>31	7	230
14.23	>31	41	329
7.1	>31	0	806



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ARISS Antenna and Satellite Antenna Tracking Interface

by Mark Spencer, WA8SME, mspencer@arrl.org

ARRL Education and Technology Program Coordinator

I encourage schools to develop a portfolio of activities that bring space technology into the classroom. One part of that portfolio can be a scheduled ham radio contact with astronauts on the International Space Station (ISS) through a program called Amateur Radio in the International Space Station (ARISS). (The application for an ARISS contact and other relevant information about ARISS can be found at: <http://www.arrl.org/ARISS/>) This is a wonderful opportunity for students to experience a connection with space pioneers via ham radio.



Photo 1: Yaesu rotator controller with the Sat688 controller on top.

There are specific station equipment requirements stipulated to qualify for an ARISS contact. "A typical ARISS ground station includes a 2-meter FM transceiver and 25-100 watts of output power. A circularly

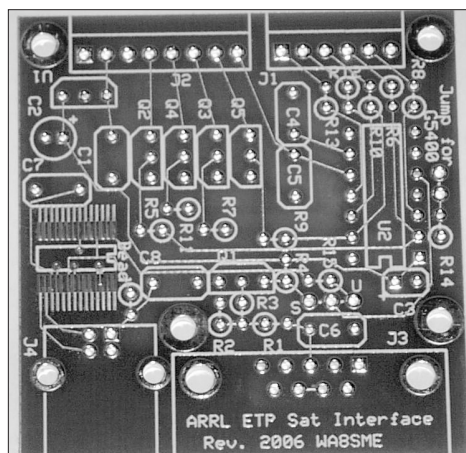


Photo 2: The Sat688 controller interface circuit board.

polarized crossed-Yagi antenna capable of being pointed in both azimuth (N-S-E-W) and elevation (degrees above the horizon) is desirable." The ARISS applicant details the station capabilities in the application by answering these questions:

- Antenna Type (Vertical, Satellite (AZ/EL?), Other) [specify]:
- If commercially built, manufacturer and model:
- Antenna Gain (dbd or dbi):
- Number of Elements:
- Polarization (Horizontal, Circular, or Vertical)
- Antenna Equipped With a Rotator? (None, Azimuth only, or AZ/EL):
- Satellite Tracking Program Available? (Yes or No):
- If Yes, Name of Tracking Program:
- Do you have Automatic Antenna Control? (Yes or No):

These station specifications can be a little intimidating and sound expensive. The ARRL Education and Technology Grant Program can help with some of the resources needed to qualify for an ARISS contact (For more information about the ARRL/ETP visit: <http://www.arrl.org/FandES/tbp/>). The following specifically describes an opportunity for schools to receive help with the automatic antenna control of the satellite antenna. Additionally, plans for an antenna that the students can build for their satellite ground station are provided.

Sat688 Satellite Antenna Tracking Interface

Automatic pointing of satellite antennas helps to improve signal quality while working with satellites and also frees the operator to focus

on the satellite contact. There are three components in an automatic pointing system; azimuth (AZ) and elevation (EL) rotors, satellite track software loaded on a computer that calculates where the antennas should be pointed in space, and an interface that connects the rotors to the computer.

Rotors are motors that turn the antenna around the compass horizon (AZ) and above the horizon (EL). Two of the few commercially available rotor systems are the Yaesu G5500 and G5400 rotors (G5400 is available on the used market). These rotors are a little pricey at approximately \$550. The Yaesu companion interface that allows a computer to control the rotors is also pricey at an additional \$550.

Common software packages that are available to track satellites include NOVA (<http://www.arrl.org/catalog/?item=8724#top>)



Photo 3: Antenna gamma match construction.



Photo 4: Gamma matches and phasing lines.



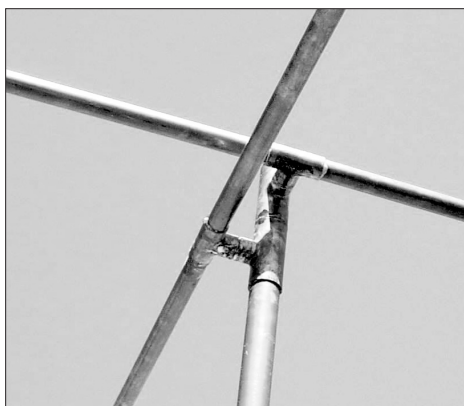


Photo 5: Element attachment technique.

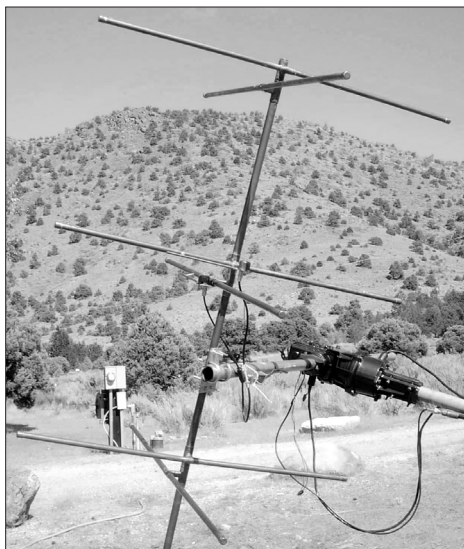


Photo 6: Boom construction.

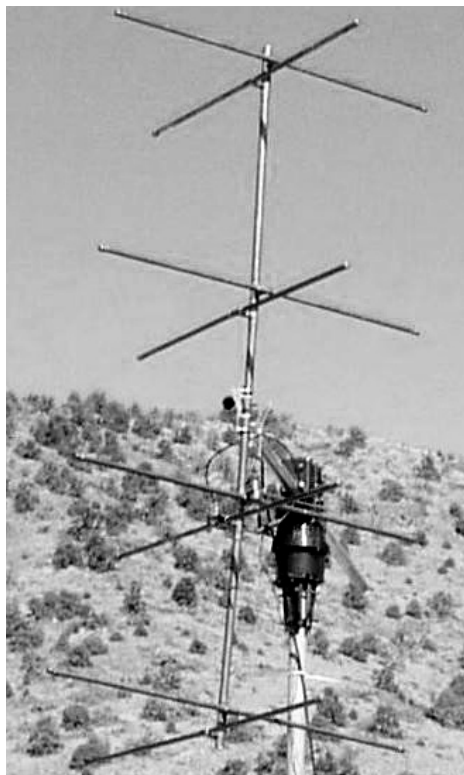


Photo 7: Completed antenna.

and SatPC32 (<http://www.amsat-na.com/item.php?id=100017>). Both these programs provide good graphics for visual display of satellite positions and also are excellent software packages to assist with instruction about orbital mechanics. Both these software packages can control rotors to point antennas.

The Sat688 interface is available through the ARRL/ETP as a grant to schools and provides an inexpensive alternative to a commercial interface unit (Photo 1). The Sat688 interface is based on a PIC that is programmed to interpret satellite position data in EASYCOM format sent by the satellite tracking software and control rotor motors. The Sat688 can be set up through jumper connections to work with both the G5500 and G5400 rotors as well as serial or USB computer connections. The interface has been tested and verified to work with NOVA and SatPC32 software.

A limited number of the interfaces are available to schools that document that they have applied for an ARISS contact and make an application for the interface through the ARRL/ETP. Contact the ARRL/ETP

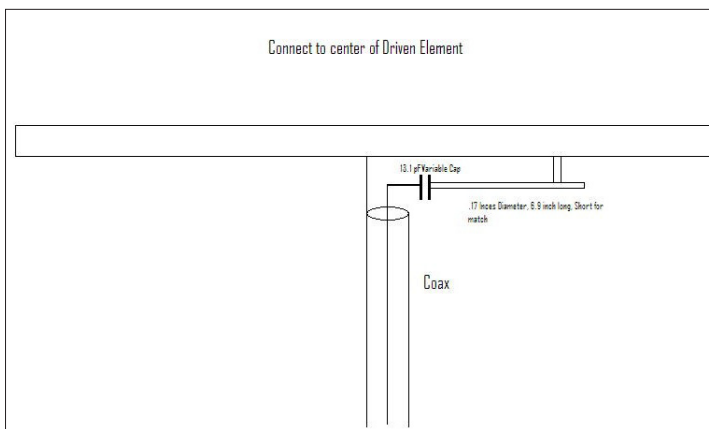
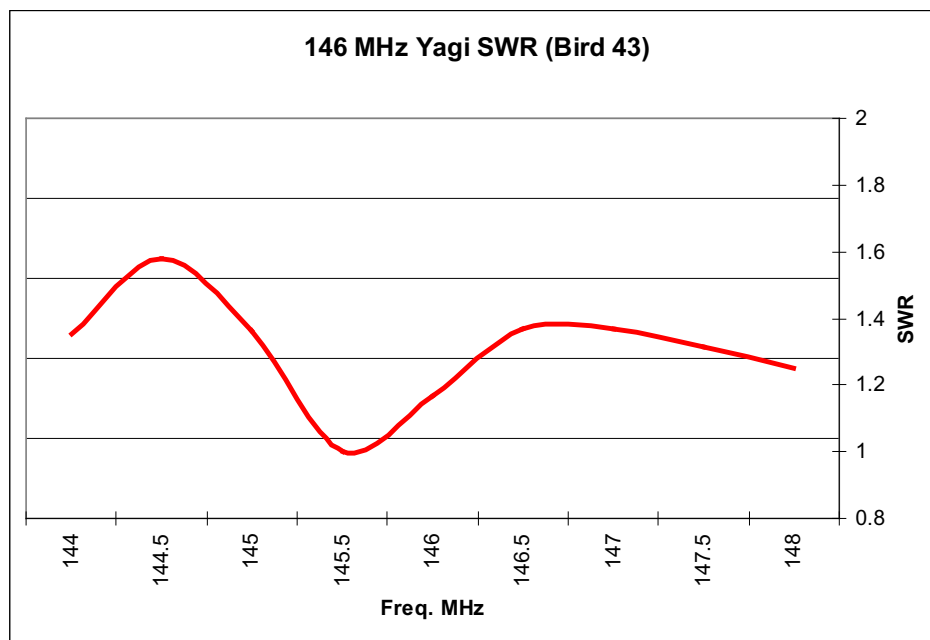


Figure 1: Gamma match configuration.

coordinator Mark Spencer, WA8SME, at mspencer@arrl.org or 530-495-9150 for application details.

For hams that are interested in the Sat688 interface, the PIC software and circuit diagram are available for the price of an e-mail request. (Ed. – Also see the last two issues of *The AMSAT Journal*.) A limited number of circuit boards (Photo 2), programmed PICs and the construction documentation are available. Contact me at mspencer@arrl.org and request details on how to obtain boards and programmed PICs. The total cost of the Sat688 interface, using new parts, is approximately \$40.

continued on the next page ...



Circularly Polarized Yagi Antenna for ARISS Contact

While building the required radio transceiver, writing satellite tracking software and building antenna rotor systems is beyond the capabilities of many, students can actively participate in the construction of their satellite ground station by building the antenna. The antenna plan presented here can easily be duplicated by the students, or better yet, engaged the industrial arts class to build the antenna and include some cross-curricular activity in the ARISS experience.

The antenna is made of ½ inch copper pipe elements and ¾ inch copper pipe for the boom. The antenna can be easily duplicated using the illustrations as a guide. The antenna elements are connected to the boom with “T” fittings. (See Photos 3 through 7 for construction suggestions and Table 1 for dimensions.) Antenna impedance matching is accomplished through a simple Gamma match network. (See Figure 1 for dimensions.) Phasing and impedance matching is accomplished through coax phasing lines as detailed in *The Radio Amateur's Satellite Handbook* pages 9-9 and 10-25.

The antenna performs very well. The SWR curve of the antenna I constructed is shown in Figure 2. The radiation pattern of the antenna as calculated is shown in Figures 3 and 4.

Conclusion

Don't let the equipment requirements to qualify for an ARISS contact prevent you from exploring this opportunity. Check out the grant opportunities offered by the ARRL/ETP, check out the Sat688 interface and look into the suggested antenna construction project presented here and you might find that you can do it. And the end result, connecting your students to the pioneers in space through ham radio, makes the effort more that worth it!

For additional information and details, contact Mark Spencer, WA8SME, mspencer@arrl.org or 530-495-9150. 📶

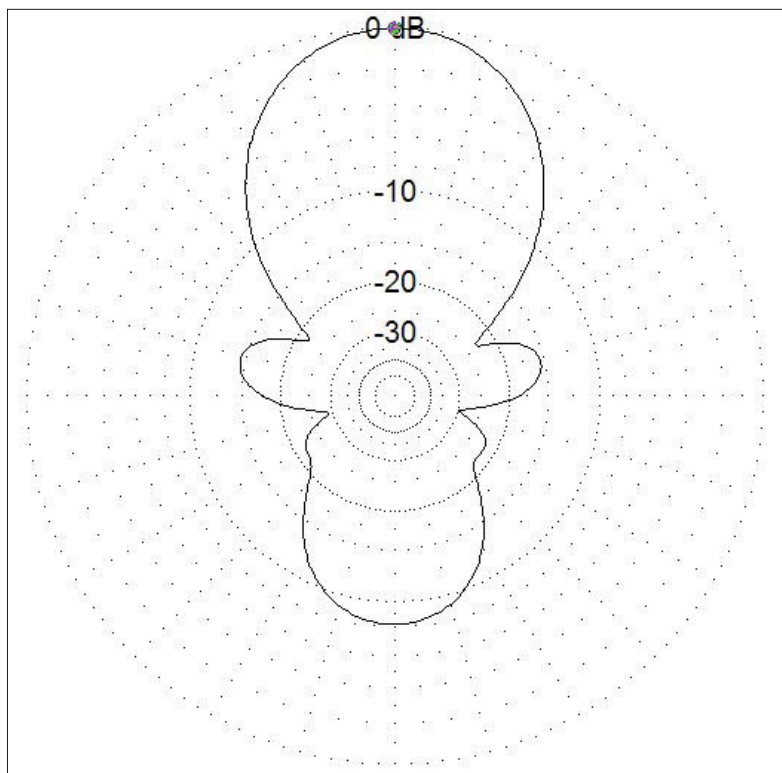


Figure 3: Horizontal radiation pattern for 2M.

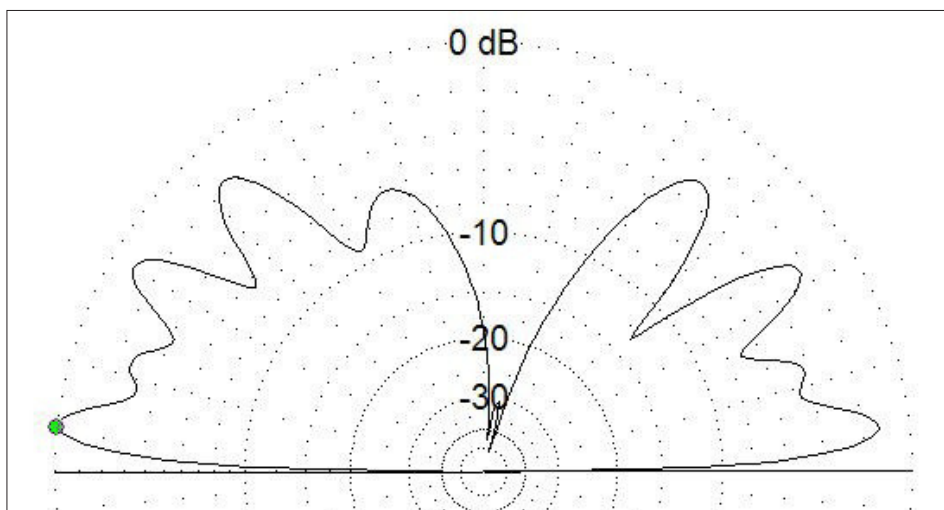


Figure 4: Vertical radiation pattern for 2M.

145 MHz Satellite Antenna Dimensions		
Element	Length	Spacing
Reflector	3.28' (39.36") [39-3/8"]	0'
Driven	3.15' (37.8") [37-13/16"]	1.44' (17.28") [17-¼"]
Director 1	2.96' (35.52") [35-½"]	1.57'(18.84") [18-7/8"]
Director 2	2.85' (34.2") [34-3/16"]	2.04'(24.48") [24-½"]

Table 1: Construction dimensions.

AMSAT EAGLE Update

by James A. Sanford, PE, WB4GCS, wb4gcs@amsat.org

Eagle Project Manager

Our Vision is to deploy high earth orbit satellite systems that offer daily coverage by 2009 and continuous coverage by 2012...

I write this update while sitting in the San Francisco airport following a very successful AMSAT Symposium and General Meeting. I always enjoy these meetings, but was particularly impressed by the quality and diversity of the presentations at this one. I also noted the rapt attention to the presentations by many attendees – the room was never empty. It was good to see all of you.

Leading up to Symposium, the Eagle Team reviewed and assessed planned communication payloads and made explicit recommendations to the AMSAT Board of Directors. The Board approved the following (just in case you haven't already seen it on the AMSAT Web page or ANS):

- A SSB/CW (etc.) transponder with uplink on U-band and downlink on V-band. System design has a goal that it be usable over 75% of the orbit by an AO-13 or AO-40 capable ground station.
- A SSB/CW (etc.) transponder with uplink on L-band and downlink on S1-band (2.4 GHz). An AO-13 or AO-40 capable ground station will be able to use this payload. It will have fixed antennas, so use will be impacted by spin modulation and by available power.
- A low rate text message system, like SMS. It will operate on U/V-bands and be usable over 75% of the orbit by a small terminal on the ground.

These transponders will be implemented using Software Defined Transponders (SDX).

Eagle will also carry an advanced communications payload (ACP). Using advanced signal processing and RF techniques, the ACP will allow:

- Voice communications on S2-band (3.4 GHz) uplink and C-band (5.8 GHz) downlink using a single 60cm dish. The antennas will be electrically steered to reduce spin modulation and allow use over 75% of the orbit. An additional, fix-pointed, uplink will be available at L-band. This will require a separate L-band uplink antenna at the ground station.

- High rate data communications, such as streaming video using a 2m dish on S2/C bands.

AMSAT will develop and make available an affordable ground segment for the ACP System.

I thank Lee McLamb, Gould Smith, and Joanne Maaenpa for their efforts in getting the word out within hours of the Board's decision and announcement. I also thank Barry Baines for his invaluable assistance during Symposium and the Board Meeting.

There were some great Eagle discussions at Symposium. Among others, Lou McFadin, W5DID, presented a description of an innovative energy storage and management subsystem. Matt Ettus, N2MJI, presented his proposal for the characteristics of the ACP downlink. If you weren't there, I encourage you to purchase and READ the Proceedings. After you're read Matt's article, read it again – Matt is doing great work on behalf of Eagle and our future users. If you weren't there, read the Proceedings.

During the AMSAT General Meeting, Wayne Estes, W9AE, asked a very good question regarding the apparent complexity of what we're designing. He asked what we're doing to make sure that Eagle **just works**. Bob McGwier, N4HY, and Tom Clark, K3IO, summarized some of the design features we're incorporating to improve reliability and flexibility. Bill Tynan added that just adding redundancy does NOT necessarily improve reliability. Instead, it merely adds switching and other requirements and introduces additional complexity which can actually REDUCE reliability. See Tom Clark's article from a year or so ago relating complexity as a function of the number of "things." It is important to recognize that some of the apparently more complex things that will be in Eagle are actually simpler, and therefore more reliable, since there are fewer single-point failures. The ability to reconfigure software on-orbit is also a reliability enhancement – if we get something wrong, despite all the testing and analysis, we can fix it.

From the perspective of the Eagle overall project, we are doing many things to address

reliability and make sure Eagle **just works**. Reliability begins in the design phase, and here's what I told the assembled members that the Eagle team is doing:

- Subsystem designs get rigorously peer reviewed, before prototyping
- We are publishing everything we do – YOU can participate
- We will have detailed test plans
- We will test everything and publish results
- We will fully characterize every module
- We will fully understand the consequences of every single module or component failure
- We will assess the risks thereof
- We will assess the mitigations and work-arounds of each plausible failure
- We will test and understand all possible modes of Eagle system operations, even if unintended
- AND, we will completely understand potential risks, consequences, and mitigations regarding anything we deliberately decide not to test

I have two personal goals for the Eagle design and construction effort that I would like to share with you:

1. As much as possible, there will be no single-point mission-killing failures.
2. There will be no surprises on orbit.

You should be very aware that his level of analysis and testing takes time and has financial costs. I personally believe that you will use a better Eagle as a result of supporting those costs.

There are some single point failures we cannot prevent, work around, or mitigate – say, a catastrophic failure at launch. That is outside our span of control.

Within our span of control, your Eagle team is doing all that we can to manage risk and prevent failure. Check out the "View from the Bridge" page in EaglePedia. You will see some failure analyses that your Eagle team has located and studied. We intend to learn from each and do not wish to repeat any. If you know of some other such analysis,





please let me know. For the record, I have already studied, in detail, the complete report of the Challenger Commission and of the Columbia Accident Investigation Board. If you are really interested in failure prevention, go read the articles on EaglePedia. Then read the Challenger and Columbia reports.

Failure analysis is not fun or pleasant. Nevertheless, it is something we must do, and these reports affect how I do business with your Eagle Team and how we design Eagle. *"Those who will not learn from the past are condemned to repeat it."* I thank Wayne for prompting me to explain what the Eagle team is doing to the Symposium attendees, and to you.

Thanks for your support. Please consider what additional support you can offer, particularly given the things the Eagle team is doing to guarantee success.

As always, questions to, wb4gcs@amsat.org

73,
Jim



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Build This Cheap and Easy Satellite Uplink Antenna

by Richard F. Crow, N2SPI, n2spi@amsat.org

Author's Note: This is a companion article to my first article titled "Build This Cheap and Easy Satellite Downlink Antenna" published in the July/August 2006 AMSAT Journal. Please read my author's note at the beginning of the first article for additional background on this series. As before, this article is a revised copy of a free handout I developed for the AMSAT booth at the 2006 Rochester, NY hamfest. It is intended to enable non-satellite hams and students who will be the future satellite hams, to painlessly acquire the 146 MHz uplink antenna needed to actually work a satellite. Feel free to copy it and give it away, along with the "downlink antenna" handout, at your next AMSAT presentation or hamfest. Also, it makes an excellent school, club or Boy Scout project. But, before I get to the handout, I'd like to touch on a couple of points:

- (1) A school, a student or anyone can also use this 146 MHz uplink antenna to downlink (receive) voice and packet data signals from the ISS (International Space Station). The ISS worldwide downlink frequency for this is 145.800 MHz. A suitable 146MHz NBFM receiver may be found in a 2m Amateur Radio HT, 2m mobile transceiver, wide band receiver or police scanner. The suggestions for tracking and receiving a satellite in the "downlink antenna" article also apply generally to the ISS. If you have a ham license you can also uplink to the ISS with this antenna as well. At www.amsat.org, click on "Satellite Information", then click on "Amateur Satellite Status", then click on "ARISS" for ISS status and frequencies. Also, see www.issfanclub.com. For introductory info about working the ISS, see www.rac.ca/ariss/faqrariss.htm and www.rac.ca/ariss/arisspak.htm.
- (2) A school, a student or anyone may be able to use this antenna to receive the signal from a future Suitsat mission, provided it transmits in the 2m band as it did before and its signal is strong enough. Most of the advice in note 1 above about receiving signals from the ISS will generally apply to SuitSat. If you're not familiar with SuitSat, Google "SuitSat" and "SuitSat-1".

Introduction

When I operate satellite portable, I uplink to the FM LEO (Low Earth Orbit) satellites (AO-27, SO-50 and AO-51) using a homemade handheld 146 MHz 3 element Yagi antenna. In the write up that follows, I'll show you how to build this inexpensive uplink antenna for yourself. If you're a satellite beginner, I recommend you start with handheld, portable antennas to avoid the expense and complication of purchasing Az/El (Azimuth and Elevation) rotators and fixed-station satellite antennas. Portability also gives you the flexibility to select and travel to an advantageous location for satellite operations if your home location is not so good.

Note there is a companion write-up titled "Build This Cheap and Easy Downlink Antenna". I will refer to this article, from time to time, as the "downlink antenna" article. You should build the downlink antenna first, and practice receiving satellite signals, before you build this uplink antenna. There is also a third article for building a cross boom with tripod which is tentatively titled "Build This Cross Boom For Your Cheap and Easy Satellite Antennas". If you find that this article is not available now, it will be soon. You'll need this cross boom and tripod to hold and separate your uplink and downlink antennas. If you can't locate copies of these other articles, see the instructions for e-mailing me at the end of this article. I'll either tell you where to find them or I'll send them to you.

Be advised that you need to possess a suitable Amateur Radio license to uplink

(transmit) to a satellite. To find out how to qualify for such a license, contact a local or national ham radio club, go to any hamfest, or visit www.arrl.org. In the United States, it's fairly easy and inexpensive, though perhaps time consuming, to study for and pass the test required to obtain the entry-level license needed.

Again, the electrical design for this antenna is from "Cheap Yagi Antennas for VHF/UHF" by Kent Britain, WA5VJB (Google "Cheap Yagi"). The mechanical construction and step-by-step presentation for this antenna is the same as in the downlink antenna article. If you built the downlink antenna, you can build this antenna. And finally, in step 57, I'll show you how to use this antenna to actually uplink to a real satellite. I think you'll be amazed by how well it works. See Photo 1.

Step-by-Step Instructions

1. Read these instructions all the way through to get an idea of what's involved. Pay particular attention to how tools are used in case you don't have one and can make a substitution with a tool you have.
2. Referring to the list of materials in Table 1, acquire the necessary materials. Note that the materials are exactly the same as those for the downlink antenna. You should have most of the materials you need left over from that project. However, for the 6-foot coax cable, it may be cheaper to purchase a 12-foot RG-58 coaxial jumper cable with BNC connectors on each end (Radio Shack #278-965). Cut the 12-foot cable in half and use one half for the downlink



Photo 1: The N2SPI Cheap and Easy Satellite Uplink Antenna.



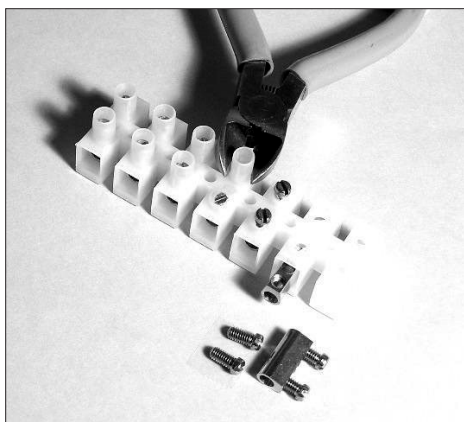


Photo 2: Terminal strip in various stages of disassembly.

antenna and the other half for the uplink antenna. Also, for the foam board, you may want to get the 30-inch by 40-inch size. You'll need this larger size later for the cross boom and Staples seems to be packaging this now as a 3-pack. With careful planning, you should be able to get a downlink antenna, an uplink antenna, a cross boom and then some out of a single 3-pack of 30 inch by 40 inch foam board. For other sources of aluminum wire, Google "aluminum ground wire".

3. Referring to the list of tools in Table 2, make sure you have the necessary tools or suitable substitutes. Note that the tools required are exactly the same as those for the downlink antenna. However for the 36" straightedge, you may prefer to acquire and substitute a 4-foot carpenter's level. You'll need the carpenter's level to make the cross boom later. Position the smaller-width side of the level against the foam board when using it as a straight edge. Refer to the downlink antenna article for additional tool comments.

In the next 4 steps, liberate two wire-to-wire connectors from the Euro-style terminal strip. The wire-to-wire connector is the secret to the "N2SPI No-Solder Connection Method".

4. Select a terminal on the Euro-style terminal strip and, using the flat 1/8" blade screwdriver, screw both screws in the terminal all the way in. Now, use the diagonal cutters to clip off the tops of both plastic screw towers just above the screw-heads. See Photo 2.
5. Unscrew both screws until they fall out. Now, push the terminal's metal barrel out of the plastic housing.
6. Now, re-install both screws into the barrel to complete the first wire-to-wire connector hereafter called a "connector".
7. Repeat steps 4 through 6 to obtain a second connector. Then, set both connectors aside. They'll be used later to attach the coaxial cable to the antenna's driven element.

In the next 4 steps, make two 2 3/4 inch by 30 inch foam board strips for the side panels on the antenna boom.

8. Position the foam-board so a 30-inch factory edge, hereafter called a factory edge, faces you. Place the two pine boards under the foam board so it is elevated and lies flat and steady. Adjust the combination square so 2-3/4 inches of the rule is sticking out of the attached head. Then, place the head of the combination square against the factory edge and, with the rule lying flat against the foam board, make two pencil marks, one 2-3/4 inches up the left side, and one 2-3/4 inches up the right side from the factory edge. Use the straight edge to draw a 30-inch line between the two marks. This general measuring procedure is hereafter called "using previous measuring methods".
9. Now, place the first pine board under the line on the foam-board so as to act as a cutting board. Place the second pine board so the foam-board lies flat and steady.
10. Be sure the X-Acto knife has a fresh, sharp blade. Now, carefully and

patiently (take your time), trace along the line with the tip of the X-Acto knife. At first, just penetrate the surface paper. Repeat, cutting a little deeper each time, and as you can, gently bend back the foam board to expose the cut. Finally, cut through to make a foam board strip, hereafter called a "strip". Using the pencil, lightly write "Factory Edge, Bottom" on the factory edge to make it the bottom edge. This general cutting procedure is hereafter called "using previous cutting methods".

11. Repeat steps 8 through 10 to produce a second 2-3/4 inch by 30-inch strip, which includes the other factory edge. These two particular strips are hereafter called "side panels".

In the next step, make three 1-1/4 inch by 30-inch foam board strips for the inner core of the antenna boom.

12. Using previous measuring and cutting methods, make three 1-1/4 inch by 30-inch strips. Note: (a) there're no more factory edges to locate, and (b) after each strip is cut, lightly write "Bottom" on its better 30-inch edge to make it the bottom edge.

In the next 3 steps, laminate the three 1 1/4 inch wide by 30 inch long strips to make the inner core of the boom.

13. From one end of a 1-1/4 inch by 30-inch strip, lay down a first piece of double-sided tape near the top edge for the first 15 inches. Then cut neatly with the X-Acto knife. In a similar way, lay down another piece of double-sided tape along the remaining 15 inches of the top edge. Using the same procedure, lay down two consecutive pieces of double-sided tape along the bottom edge.
14. Lay the first strip down on your worktable with the double-sided tape facing up. Then, take a second 1-1/4 inch by 30-inch strip, line up the bottom edges and one end of the two strips. Starting at the one end, progressively

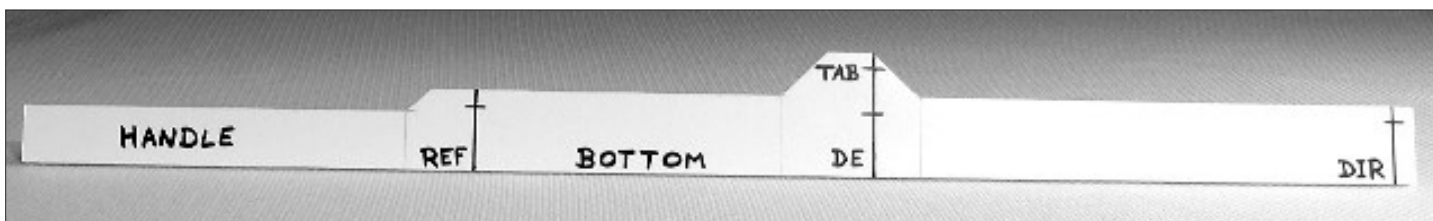


Photo 3: Side panel with element positions marked (markings made very dark for illustrative purposes).





press the second strip onto the first, keeping the bottom edges lined-up, until you're done. If strips are warped, combine the warp of one strip with and an opposite warp from the other strip, so they cancel out.

15. Repeat steps 13 and 14, hereafter called "using previous laminating methods", to laminate the third 1-1/4 inch by 30-inch strip together with the first two.

In the next 5 steps, cut the left side of a tab in the first side panel to accommodate the driven element hairpin wire.

16. Using the tape measure plus previous measuring methods, from the bottom left corner of a side panel, measure 16 inches to the right along the factory edge and make a first mark. Then, at this first mark, use the combination square to draw a line perpendicular to the factory edge and across the side panel. See Photo 3.
17. Now, from the factory edge, measure and make a second mark 1-3/4 inches up the perpendicular line just made in the step above.
18. Then, again from the factory edge, measure and make a third mark 1-3/4 inches up the left side of the side panel.
19. Use the straight edge to draw a 16-inch line from the third mark to the second mark. Place the combination square's 45 degree surface against the factory edge and extend and position the rule so you can draw a 45 degree line from the second mark to the right and up to the top edge of the side panel.
20. Using previous cutting methods, cut along the 16 inch and 45 degree lines making a curved transition at their junction. See Photo 3.

In the next 5 steps, cut the remaining right side of the tab in the first side panel.

21. Using previous measuring methods, from the bottom right corner of the same side panel as above, measure 11 inches to the left along the factory edge and make a first mark. Then, at this first mark, use the combination square to draw a line perpendicular to the factory edge and across the side panel.
22. Now, from the factory edge, measure and make a second mark 1-3/4 inches up the perpendicular line just made in the step above.

23. Then, again from the factory edge, measure and make a third mark 1-3/4 inches up the right side of the side panel.

24. Use the straight edge to draw an 11-inch line from the second mark to the third mark. Place the combination square's 45 degree surface against the factory edge and extend and position the rule so you can draw a 45 degree line from the second mark to the left and up to the top edge of the side panel.

25. Using previous cutting methods, cut along the 11 inch and 45 degree lines making a curved transition at their junction. See Photo 3.

In the next step, cut a tab in the second side panel.

26. Repeat steps 16 through 25 to cut an identical tab in the second side panel.

In the next 5 steps, cut a handle out of the first side panel.

27. Using previous measuring methods, from the bottom left corner of a side panel, measure 8 inches to the right along the factory edge and make a first mark. Then, at this first mark, use the combination square to draw a line perpendicular to the factory edge and across the side panel. See Photo 3.

28. Now, from the factory edge, measure and make a second mark 1-1/4 inches up the perpendicular line just made in the step above.

29. Then, again from the factory edge, measure and make a third mark 1-1/4 inches up the left side of the side panel.

30. Use the straight edge to draw an 8-inch line from the third mark to the second mark. Place the combination square's 45 degree surface against the factory edge and extend and position the rule so you can draw a 45 degree line from the second mark to the right and up to the top edge.

31. Using previous cutting methods, cut along the 8 inch and 45 degree lines making a curved transition at their junction. See Photo 3.

In the next step, cut a handle out of the second side panel.

32. Repeat steps 27 through 31 to cut an identical handle out of the second side panel. Note that both side panels now have a 1-3/4 inch wide end and a 1-1/4

inch narrow end.

In the next 4 steps, mark both side panels to show where the antenna elements will pass through.

33. Refer to Table 3. Use the combination square to measure along the top edge and make a mark 1/2 inch in from the wide end. This mark partially locates where the antenna's director element will go. Use the tape measure to measure along the top edge from the wide end and mark the remaining two element positions.

34. Now, at each marked element position on the top edge, use the combination square to draw a line perpendicular to the factory edge and across the side panel.

35. Then, re-adjust the combination square to measure and place a cross-mark on each perpendicular line at a point 1-3/8 inches up from the factory edge. At the driven element line only, make a second cross-mark 2-3/8 inches up from the factory edge. See Photo 3.

36. Repeat Steps 33 through 35 to mark the element holes for second side panel in the same way as the first, EXCEPT on the opposite side than the first. (i.e., the second side panel's markings are a mirror image of the first side panel's markings.)

In the next step, make element holes in the first side panel only.

37. Place the first side panel on a pine board and push the skewer partway through at an element location until it just barely pokes through. Make sure the skewer is perpendicular to the first side panel when you do this. Wiggle the skewer slightly if it helps. Then turn the side panel over and poke the skewer back through, all the way, to complete the hole. Do this for all four element holes.

In the next 2 steps, laminate the side panels to the inner core of the antenna's boom.

38. Position the first side panel so the element position markings are facing one side of the inner core. Now, using previous laminating methods, laminate the first side panel to the inner core.

39. Using previous laminating methods, laminate the second side panel to the other side of the inner core, AFTER lining-up the wide end(s) and bottom



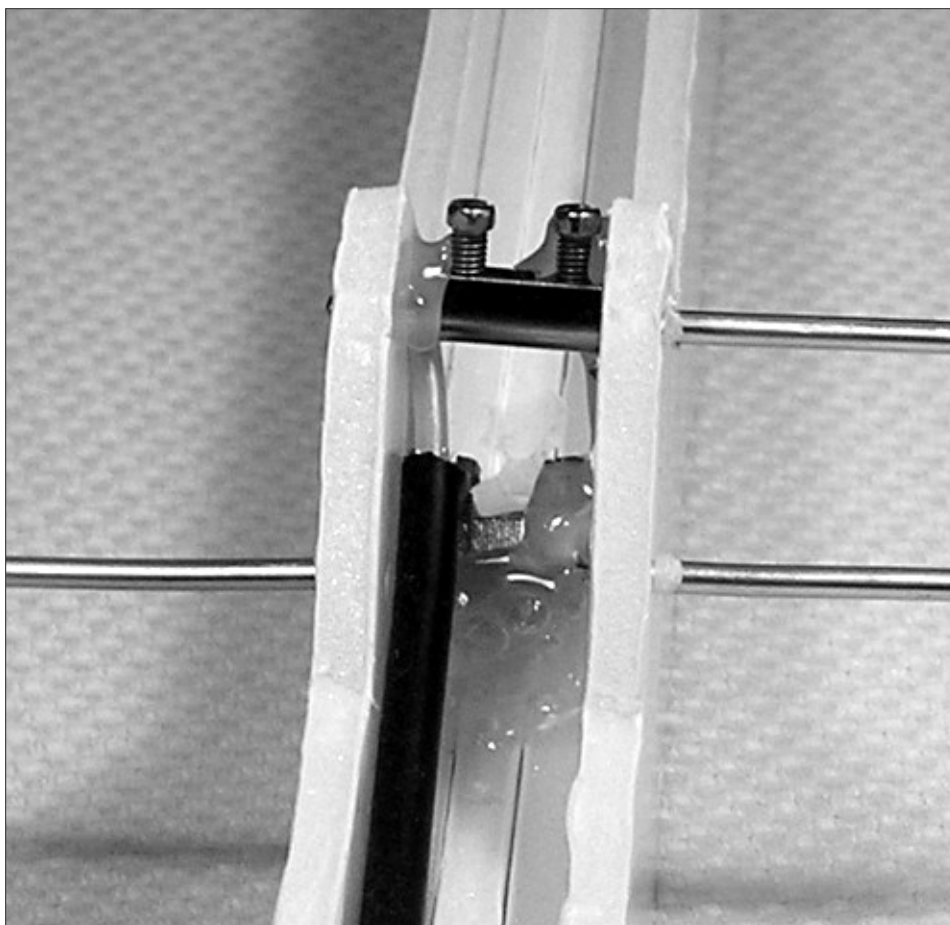


Photo 4: Driven element detail.

edge(s) of both side panels. Now, wrap the handle with one layer of clear packing tape.

In the next step, finish making the antenna element holes.

40. Re-push the skewer through the antenna's reflector element hole in the first side panel until it just touches the associated cross-mark on the second side panel. Use the combination square to verify the skewer is perpendicular with respect to the boom. If not, adjust the actual puncture point so the skewer is perpendicular to the boom. Then, using the method in step 37, make the hole. Repeat this until all four element holes in the second side panel are made.

In the next 4 steps, fabricate the antenna's driven element out of #8 AWG aluminum wire.

41. Straighten out a 60-inch length (hereafter called a "wire") from the #8 AWG aluminum ground wire. Use the tape measure and permanent marker to make a mark 20-1/2 inches in from a wire-end. At the mark, bend the wire around

a piece of 7/8 inch O.D. pipe or tubing until the short segment is parallel with the long segment. If you have nothing else, bend the wire around a "C" size flashlight battery. Re-bend, if necessary, until the two segments are spaced 1 inch apart. If the aluminum wire dirties your hands, wipe it down with paper towels dampened with a spray cleaner such as Windex.

42. Use the tape measure to measure 38-1/2 inches along the long segment starting from the bend. Mark and final-cut the wire here as follows: With the diagonal

cutters, cut the wire halfway, rotate the wire 90 degrees, and cut halfway again. Then bend the wire back and forth until it snaps in two. Use the mill file to bevel and smooth over the remaining rough and sharp edges. Use this method to get a smooth, rounded wire-end whenever a final-cut is called for.

43. Find the halfway point, or center, of the long segment. This should be $38\text{-}1/2 \text{ inches} / 2 = 19\text{-}1/4 \text{ inches}$. Now, get ready to make two marks, the first $5/8 \text{ inches}$ to the left, and the second $5/8 \text{ inches}$ to the right, of the center. To do this, measure and mark $19\text{-}1/4 \text{ inches} - 5/8 \text{ inches} = 18\text{-}5/8 \text{ inches}$ in from the bend, and also $18\text{-}5/8 \text{ inches}$ from the cut end. These marks will help you to center the element later.
44. Now, final-cut the short wire segment to $19\text{-}13/16 \text{ inches}$ measured from the bend.

In the next 4 steps, prepare the coaxial cable.

45. Take the RG-58 coaxial cable assembly (hereafter called the "cable") and use the diagonal cutters to cut off one of the BNC connectors so the remaining cable is about 6 feet long. Measure and mark the cable jacket 3 inches down from the cut end.
46. Be sure the X-Acto knife has a fresh, sharp blade. Place the cable on a pine board and gently roll it back and forth under the X-Acto knife to cut halfway through the jacket, all the way around, at the mark. Gently bend the jacket back to examine, and promote, the depth of the cut. Use a similar technique to slit the jacket from here up to the cable-end, cutting through the jacket only as you near the end. Now, pull the rest of the jacket apart and remove it.

Table 1: List of Materials

Qty Used	Material Description *	Example Source	Item Number **
1	"Elmer's" 20 inch x 30 inch Foam Board	Staples	245555
240"	1/2" wide "Scotch 665" Double Sided Tape	Staples	130500
36"	Clear Wide Cellophane Packing Tape	Staples	490802
144"	#8 AWG Aluminum Ground Wire	Radio Shack	15-035
1	Euro-style 12 mm Terminal Strip	Radio Shack	274-677
1	RG-58 Coax Jumper Cable, BNC to BNC, 6 Ft.	Radio Shack	278-964

* Name in "quotes" is the brand of product I used. Equivalents should be OK.

** Some Example Source Item Numbers come packaged in higher quantities than the quantity used.





Photo 5: Uplink antenna, cross boom and downlink antenna, ready for AMSAT's AO-51 Echo satellite.

47. Unbraid the shield wires until stopped by the new jacket end-point. Trim off half the shield wires and twist the remaining wires clockwise to form a 3-inch long, 18 AWG-size bare stranded wire shield conductor.

48. Cut the center conductor to a 2-inch length. In a way similar to step 46, cut the center conductor insulation halfway, all the way around, 1/2 inch down from the wire-end. Twist the insulation clockwise to complete the cut, then twist and pull it off. Similarly, remove another 1/2 inch, and then another. Use the 4" long nose pliers, as needed, to twist and pull-off the center insulation. In the end, the visible center conductor should have 1/2 inch of insulation remaining, and from there to wire-end, 1-1/2 inches of bare, clockwise-twisted wire.

In the next 3 steps, install the Driven Element, and attach coax using the "N2SPI No-Solder Connection Method".

49. Back-off the screws in both connectors, if necessary, until no screws are entering the wire chamber. Then, slide one connector over the coaxial cable shield conductor. Note that later in this step both the shield wire and the driven element wire should fit inside the connector. Locate the pair of holes in the side panel for the driven element's

long segment. Place the connector with the shield wire between these holes with its screws facing forward and tilted up. The coax shield should come out of the side of the connector opposite the first hole, which the driven element will pass through. Then, push the long element segment through the hole in the side panel and into the connector. As you're doing this, use the 4" long nose pliers, as needed, to position and hold things in place. See Photo 4.

50. Slide the other connector over the coax center conductor. Locate the pair of holes in the side panel to be used by the driven element's short segment. Place the connector installed on the center conductor between these holes with its screws facing up. The center conductor should be on the same side as the shield. Push the short segment through the side panel into the connector, while moving more of the long segment. Keep pushing the short segment through the connector until a little bit of it passes into the other side panel but doesn't extend beyond it. Having the short segment, as well as the long, held by both side panels considerably strengthens the attachment of the driven element to the boom. See Photo 4.

51. When the driven element is centered, and its hairpin is straight and not twisted,

and the pigtails between the coax and connector are 5/8 inch in length, tighten all screws. Apply a couple of dabs of hot-melt glue to hold the driven element in place, and then trim the excess wire with the X-Acto knife.

In the last 5 assembly steps, cut the remaining antenna elements out of the #8 AWG aluminum wire and install them.

52. Final-cut two 42-inch straightened lengths out of the #8 AWG aluminum wire.

53. Refer to Table 3. From the final-cut end of a 42-inch wire, use the tape measure to carefully measure and mark the specified length of each element. Then final-cut each element. (i.e., both wire-ends receive the final-cut treatment.)

54. In a way similar to step 43, find each element's center. Make two marks +/- 5/8 inches from the center of each element.

55. Locate the pair of holes for each remaining antenna element in the side panels. Push each element through their pair of holes and then center them. Rotate the element wire while you push if it helps.

56. Apply a dab of hot-melt glue to the middle of each element to hold it in place. When done, use hot-melt glue to secure the coax in a couple of places inside the boom. Then, use packing tape to secure the coax to the top of the handle.

And finally, test your new satellite uplink antenna.

57. Test your new satellite antenna by using it to actually uplink to a satellite, say AMSAT's AO-51. See Photo 5. To do this:

- a) First, consider how you'll handle your two satellite antennas, your downlink and now your new uplink antenna. You'll probably want to have a cross boom and tripod to hold these antennas. In the next article in this series, I'll explain how you can build this. See the introduction to this write up.
- b) Connect your new uplink antenna to a 146 MHz NBFM transmitter. Such a transmitter can be found in a 2m HT (handheld transceiver) or a 2m mobile transceiver. Use whatever you have. If you use a mobile transceiver, switch the transmit power to a level you feel



is safe. Power your mobile transceiver with one of those 12 VDC power packs with attached automotive jumper cables. For most mobile transceivers, the power pack must be able to supply at least 10 amps, or so, though its cigarette lighter socket. Note that your 2m transceiver must be able to transmit a subaudible PL tone of 67 Hz to access AO-51. Personally, when I operate satellite-HT, I use an Icom IC-T2H Sport 2m HT (\$100 at www.aesham.com). For satellite-portable, I use a Yaesu FT-1802M 2m mobile transceiver (\$150 at www.aesham.com). Sometimes I wear a carpenter's tool belt, with several large pockets, to hold all my gear. Most of the time, a 5 watt 2m HT will work quite nicely provided AO-51 is at least several degrees above the horizon and there aren't a lot of stations vying for the single uplink frequency.

c) Even though this uplink antenna works very well, there will be times you won't be able to compete with the multitude of powerful home-based stations on AO-51, particularly on the weekends. The answer to this, in my opinion, is strategy. You need to pick a good time and location before attempting to work AO-51. For example, here in the northeast USA, I take my portable satellite station to a location with an excellent northern horizon. That way I can work AO-51 while it's over northern

Canada when only a few USA hams can access it. Such a location might be a hill with a good view to the north, or the south shore of a lake. Also, consider working AO-51 on a weekday morning when it's likely the congestion will be much reduced. Initially, whatever location and time you pick, be sure AO-51 will be in unobstructed sky for the interval that you intend to uplink to it.

- d) Once you've decided on an operating location, you'll need to be able to track AO-51. Everything in the downlink antenna article concerning tracking applies here. If you can hear AO-51, you can transmit to it. Refer to step 43 in the downlink antenna article for info on tracking. Note, however, that as you get more active on the satellites, you'll probably want to have your own tracking software to run on your PC. To purchase tracking software, click on "The AMSAT Store" at www.amsat.org. Personally, I use InstantTrack v1.50, which is available to AMSAT members for \$30, a bargain in my opinion.
- e) Check the AO-51 Schedule to make sure AO-51 is operating in V/U mode. If so, adjust your 2m FM transceiver to a transmit frequency of 145.920 MHz, the "V" uplink frequency. Don't forget to transmit the 67 Hz PL tone.
- f) When you've set up your portable satellite station at your chosen operating

location, and you're ready to uplink to AO-51, wait! Aim both your uplink and downlink antennas in the direction of AO-51 and listen for it first. A lot of interference is caused by operators who transmit to a satellite over and over when it's clear they can't hear the downlink. When you do hear AO-51's downlink, and there's a break in transmissions, transmit your call sign. If everything is working, you'll hear yourself on the downlink as you transmit. It's important that you hear yourself so you can determine if you're getting into the satellite clearly, or, if there's a problem. Because you can hear yourself while you transmit, it's important that you wear full-cup headphones. Otherwise, you'll create a different sort of interference with the squeal from your audio feedback. If you're receiving a clear signal from the satellite, but your uplink is noisy, try rotating your uplink antenna around its boom axis to maximize your signal into the satellite. Other FM satellites to try are AO-27 and SO-50.

In Conclusion...

If you need assistance building or using this satellite uplink antenna, or have other questions or comments, contact me at: n2spi@amsat.org. Please put the phrase "Satellite Uplink Antenna v2.0" somewhere on the email subject line. 🌐

Table 2: List of Tools

Tool Description	Example Source	Item Number
16" Combination Square	Sears	00939681000
Small Tape Measure	Sears	00937396000
Flat 1/8" Blade Screwdriver	Sears	00941421000
6" Diagonal Cutters	Sears	00945075000
4" Long Nose Pliers	Sears	00945698000
Mill File	Sears	00931300000
"Sharpie" Ultra Fine Point Permanent Marker	Staples	498386
"X-Acto" Knife with #11 Blade	Staples	506998
"X-Acto" #11 Blade Refills	Staples	428300
Hot Melt Glue Gun with Glue Stick	Staples	508701
36" Straight Edge (Metal Yardstick)	Wal-Mart	
1/16" Square Shish-Kebab Skewer	Supermarket	
36" long Pine Boards, Qty = 2	Lumberyard	
Sharpened Pencil		

Table 3: Element Positions and Element Lengths for the 146 MHz Uplink Antenna

Antenna Element Name	Element Position from the "Wide End" (in inches)	Element Length* (in inches)
Director (DIR)	1/2	37
Driven Element (DE)	12	38-1/2
Reflector (REF)	20-1/2	41

* Try to cut the element length to within +/- 1/32 of an inch.





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